CALIFORNIA HIGH-SPEED TRAIN

Program Environmental Impact Report/Environmental Impact Statement

FINAL

Alignment Refinement/Optimization and Evaluation of the Quantm System

April 30, 2002

Prepared for:

California High-Speed Rail Authority

U.S. Department of Transportation
Federal Railroad Administration

CALIFORNIA HIGH SPEED RAIL AUTHORITY

U.S. Department of Transportation
Federal Railroad Administration

CALIFORNIA HIGH-SPEED TRAIN PROGRAM EIR/EIS

Task 2.2.b

Alignment Refinement/Optimization and Evaluation of the Quantm System

Prepared by:

Parsons Brinckerhoff, Inc.

In Association with:

P&D Environmental
Parsons Transportation Group
QUANTM Limited

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S.0 SUMMARY

As part of the program environmental process for a statewide high-speed train system, the Authority is currently conducting a screening evaluation of alignment options to focus the upcoming technical studies. The alignments considered in this screening process have been largely constrained by land use related issues and/or associated environmental constraints. However, there are two areas of the statewide system where this is not the case. Instead, the alignment options and associated costs are more constrained by physical features and associated environmental constraints. These areas are; the northern mountain crossing (Diablo Mountain Range) between the Central Valley and the San Francisco Bay Area, and the southern mountain crossing (Tehachapi Mountain Range) between Los Angeles and Bakersfield. While these areas have been previously studied and evaluated, screening decisions have been difficult since the distinction between alignments is often blurred due to the vast potential for variation in specific alignment (horizontal and vertical) and associated costs and impacts. Even in areas like the southern mountain crossing where the studies have focused on three primary corridors, the potential for differing alignment and grade options can present a significant difference in cost and impact in a given corridor.

Up until now, the Authority has used the standard and "best practices" for conceptual engineering corridor evaluation analyses. Recently, the Authority became aware of a new automated alignment optimization system developed and applied in Australia called "Quantm". Due to the potential for a wide range of impacts within the mountain passes, the Authority embarked upon an alignment optimization and refinement effort to further clarify the screening decisions using the Quantm system. Building on the previous work, this study analyzed <u>millions</u> of horizontal and vertical alignment over a three-week period. While Quantm has been widely utilized in Australia, the Authority's work is the first application of this optimization system in North America.

S.1 STUDY PURPOSE AND OBJECTIVES

The purpose of the alignment refinement/optimization study is to further clarify and strengthen the technical basis for making screening level decisions on the potential high-speed train corridors in the northern and southern mountain crossings. This study is intended to analyze the range of horizontal and vertical alignment options in an iterative manner to provide more confidence that the optimal alignments are being considered and more certainty concerning the cost estimates and potential impacts of each alignment option. To this end, the study was intended to meet the following three objectives:

- To confirm the general corridors considered in the screening studies to date and/or identify any other corridors of equal or greater viability that may have been overlooked in previous studies.
- To refine the alignment options in each general corridor to identify the most viable options in terms of infrastructure requirements and impact minimization.
- To test the sensitivity of the alignment options in each corridor to key defining criteria such as vertical grade, alignment geometry, infrastructure (tunnel, structure) costs and key environmental constraints.

This study was originally scoped to address only the southern mountain crossing. Based on the findings of the Tunneling Conference, which was held on December 3 and 4, and initial results from the Quantm analysis of the southern mountain crossing, the Authority recognized the need for further investigation of alternatives for the northern mountain crossing. Additional funds were identified, and a subsequent agreement was reached to use the Quantm tool to also address the northern mountain pass.

S.2 THE QUANTM SYSTEM

The Quantm system is a unique route optimization technology supported by a team that incorporates road and rail engineers, Geographic Information Systems (GIS) technicians, mathematicians, transport researchers and system developers. The Quantm system is an automated route selection and optimization tool that carries out automated alignment searches and corridor screening based on client or user specified geometry, constraints and cost parameters.

S.3 STUDY PROCESS

A study team comprised of key members of the Program Management Team and the Los Angeles to Bakersfield and Merced to Bay Area Regional Teams was brought together and supported by Quantm Australia personnel who traveled to Orange County for three weeks of training and assistance. Available terrain data, environmental constraints and design and cost parameters were input into the Quantm system by the team and the data compiled during this period formed the basic platform for first stage Quantm corridor screening and optimization studies.

Numerous specific alignment options were considered in each of the primary corridors in each mountain crossing. In addition, each alignment was evaluated for maximum vertical grades of 2.5% and 3.5%[1]. The conclusions from the concurrently held tunneling conference were also incorporated into the Quantm analysis. The input data for these runs was sent via email to Quantm in Melbourne and the optimization outputs were available for review just hours later. The Quantm System identified and costed approximately 12 million alignment options with each run and output the best range of lowest cost alignments that endeavour to meet the various constraint parameters. The results below were achieved in three weeks.

S.4 RESULTS AND CONCLUSIONS

In the summary below, the results of the Quantm alignment refinement and optimization study are compared to the alignment options developed during the current alignment screening evaluation as well as alignment options that were developed in the previous Corridor Evaluation Study (1999). There is typically a wide difference in the infrastructure requirements (tunnel and structure length) of the alignment options developed in these two studies, due to the differing objectives of the two studies. It is important to note that the current screening evaluation focused on minimizing potential environmental impacts, while the previous corridor evaluation study focused on minimizing tunnel requirements and cost. Based upon the results of the Tunneling Conference, the Quantm study has attempted to minimize tunneling and capital costs, and therefore is more comparable to the earlier Corridor Evaluation Study results.

S.4.1 Northern Mountain Crossing – Diablo Mountains

A. Diablo Range Direct Alignment (previously Northern Direct Tunnel)

Of the two primary corridors being considered in the Diablo Mountain Crossing, the northern alignment is advantageous in terms of travel time; however, the terrain is more difficult and remote. Because of time and resource constraints, the previous northern alignment studies in the screening evaluation had assumed that the crossing needed to be completely in tunnel because of the difficult and remote terrain.

[1] The Quantm system was also applied to identify the potential infrastructure requirements and cost associated with 5% maximum grades for comparative purposes.

As a result, the only alignment considered included a 31 mile long tunnel through the mountain crossing. A tunnel of this length, however, is costly and difficult to construct.

Using the Quantm system the study team was able to identify an alignment at a maximum grade of 3.5% that minimizes tunneling to a total of 11.3 miles and limits single tunnel length to just over 5 miles – reducing the associated construction cost by at least $2 billion. Figure S-1 shows the refined northern crossing alignment and profile. The alignment would cross three active and potentially active faults at-grade including the Ortigalita Fault, the southern extension of the Greenville Fault trend, and the Calaveras Fault zone. The most negative aspects of this alignment are that it bisects a portion of the Henry W. Coe State Park and it is located several miles south of the nearest access road SR-130.

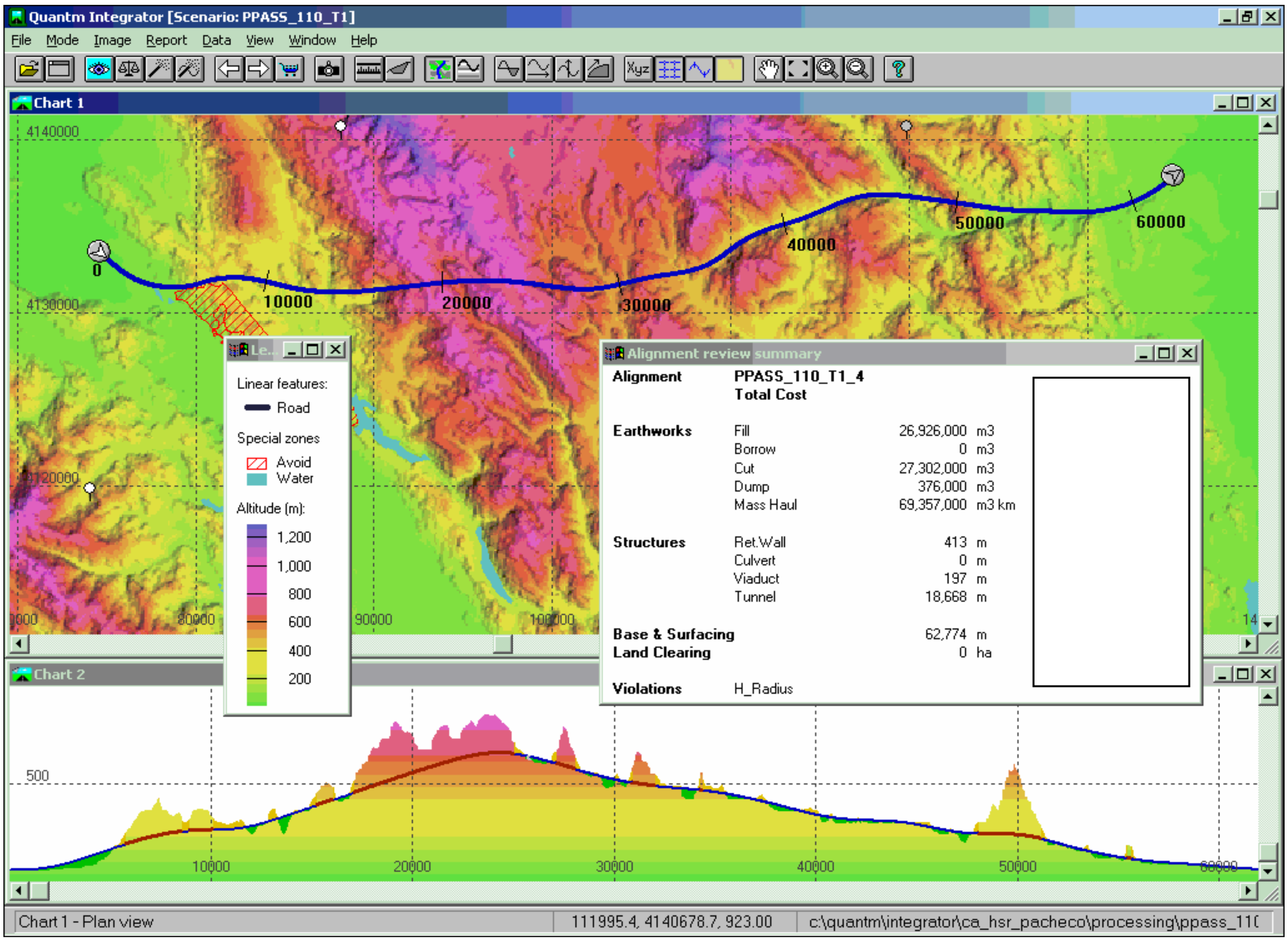

FIGURE S-1: DIABLO RANGE DIRECT – QUANTM ALIGNMENT AT 3.5% MAXIMUM GRADE

As a possible avoidance alternative to potential impacts to the Henry W. Coe State Park, an additional alignment was developed for the northern crossing that minimizes tunneling (requiring about one-half of the tunneling proposed in the previous direct tunnel option), avoids direct impact to the Henry W. Coe State Park (a key environmental constraint) and is located in close proximity to SR-130 to provide construction access. This avoidance alignment option has a total tunnel length of 16 miles and a maximum length of continuous tunnel of less than 6 miles.

B. SR-152 – Pacheco Pass

The previous alignment option considered in the screening evaluation required a total length of 18 miles of tunnel with a maximum length of continuous tunnel of 15 miles. The alignment option identified in the previous Corridor Evaluation Study (1999) required 12 miles of tunnel with a maximum segment length of 4.5 miles. Refinement of this SR-152/Pacheco Pass alignment identified an alignment and profile option that can potentially reduce the total required tunneling to only 5 miles. Figure S-2 shows the refined SR-152/Pacheco Pass alignment option.

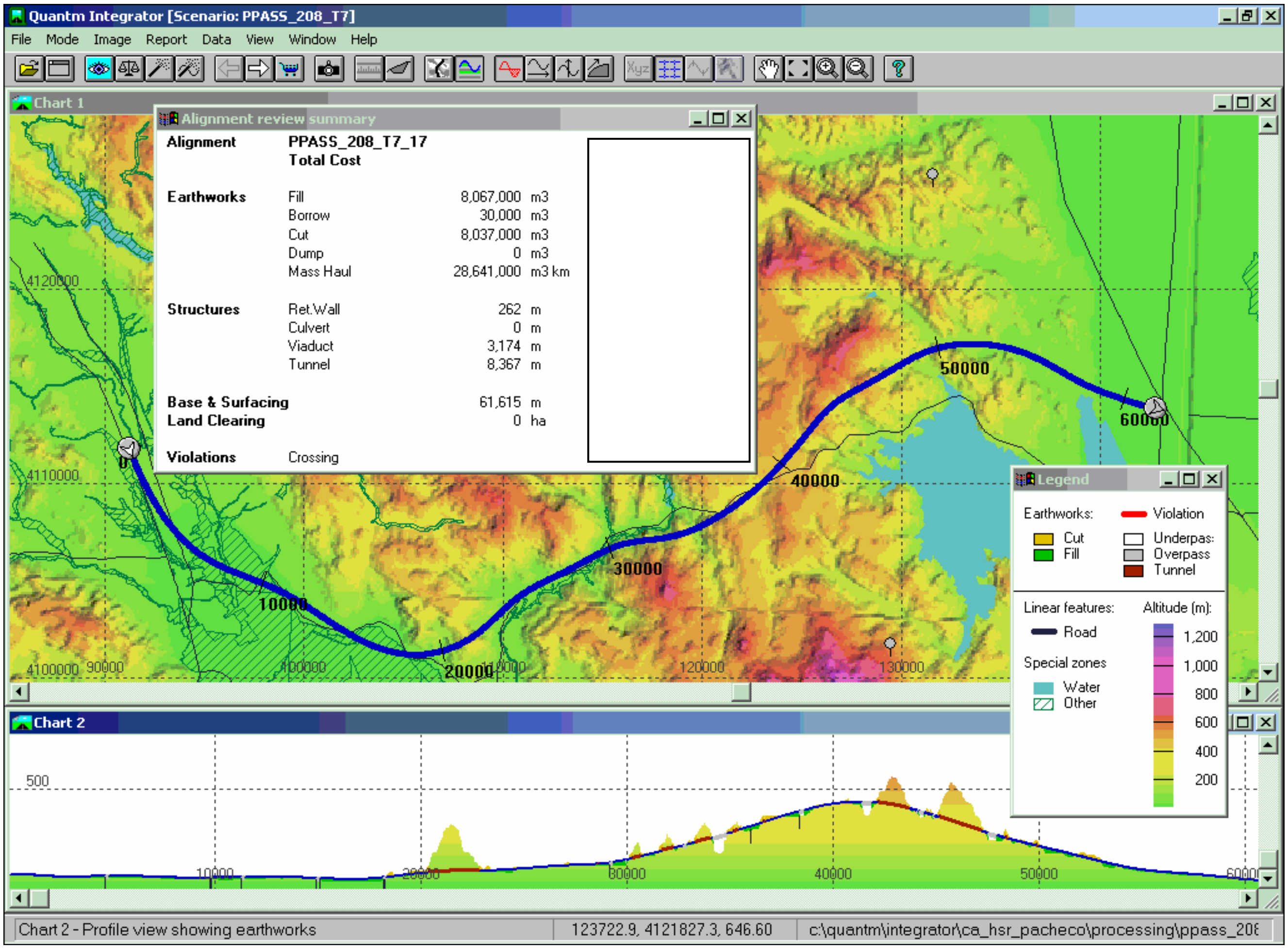

FIGURE S-2: PACHECO PASS – QUANTM SR-152 ALIGNMENT (MAX. 3.5% GRADE)

S.4.2 Southern Mountain Crossing - Tehachapi Mountains

In the Tehachapi Mountain Crossing the alignment refinement/optimization study confirmed the location of the general corridors considered in the screening studies to date.

A. I-5/Grapevine

The alignment refinement/optimization study confirmed past findings as well as identified new alignment options in key seismically constrained areas.

Alignment options using 2.5% maximum grades are unable to cross major faults at grade and require a continuous tunnel segment of at least 16 miles. However, alignment options using 3.5% maximum grades were found to provide more flexibility in avoiding the major faults at-grade than previously thought. The alignment options in the I-5 corridor were refined to identify more viable options in the area of the major fault crossings in terms of tunnel requirements, construction difficulty and cost. An alignment was identified to the east of I-5 that allows for an at-grade crossing of the San Andreas Fault zone and an at-grade or trenched crossing of the Garlock Fault zone with no single tunnel longer than 6 miles. This alignment option, as shown in Figure S-3, would require a total of 18 miles of tunneling as compared to 28 – 35 miles of tunneling required for alignment options previously studied. This alignment would require extensive construction in the floodplain area surrounding Castac Lake. The potential impacts will need to be further studied in the program environmental analysis.

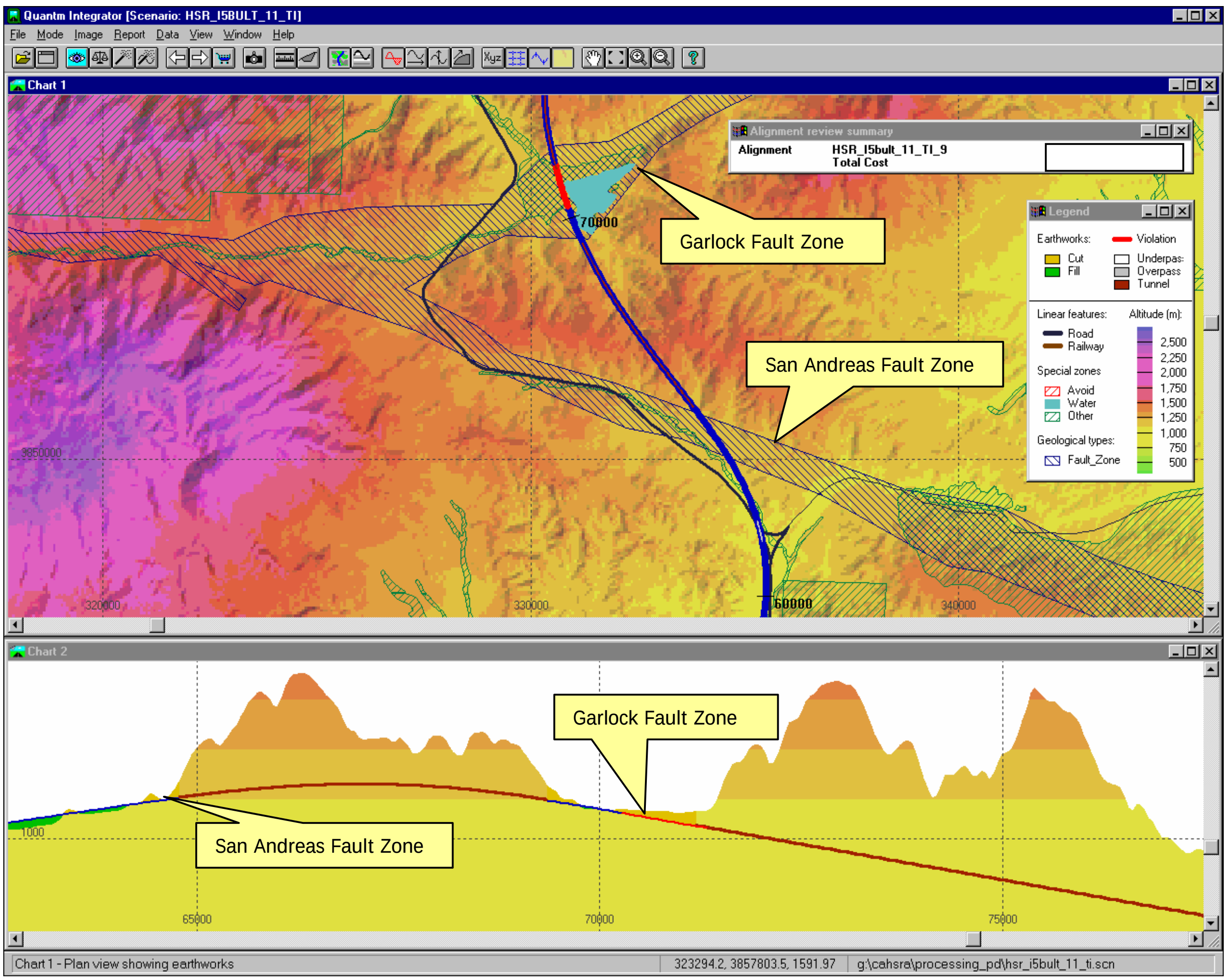

FIGURE S-3: I-5 QUANTM ALIGNMENT TO EAST OF I-5 CORRIDOR, CROSSING FAULT LINES AT GRADE

B. SR-58 / Mojave

This corridor was investigated in sections: the southern section from Sylmar to Palmdale, the middle section through Palmdale and Lancaster, and the northern section from Lancaster to the Central Valley floor. The middle section is highly constrained due to existing development and transportation corridors.

The northern and southern sections were studied more extensively because of the potential for alignment refinement in the mountainous terrain.

Southern Section (Sylmar to Palmdale) - Two corridor alternatives were studied in the southern section, the SR-14 corridor and the Soledad Canyon corridor. The alignment options in these corridors were refined to identify more viable options or reductions in infrastructure requirements and cost. The Soledad Canyon alignment option developed in the screening assumed tunneling along the north side of Soledad Canyon to avoid potential environmental impacts. By eliminating that constraint and taking a more aggressive approach to earthworks, tunneling can be reduced by as much as 16 miles as compared to the alignment option developed in the screening evaluation. The Quantm alignment option was very similar to that developed in the previous corridor evaluation in terms of required tunneling (5 miles total).

Based on that reduction, the Soledad Canyon alignment option allowed for lesser infrastructure requirements (over 3 miles less tunnel) and cost than the refined SR-14 alignment option. Figure S-4 shows the Soledad Canyon alignment option. Figure S-5 shows the refined SR-14 alignment option.

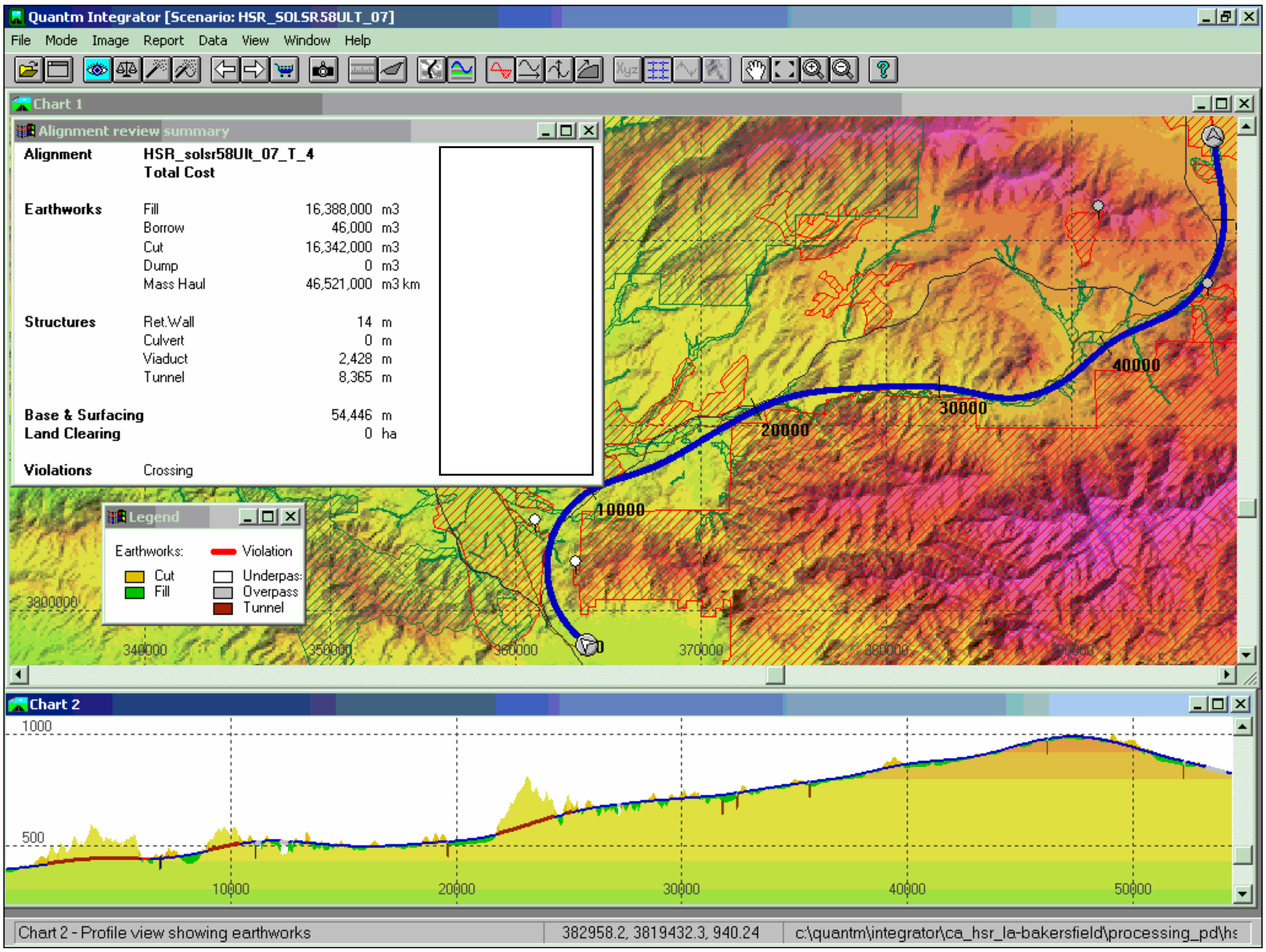

FIGURE S-4: SOLEDAD CANYON – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

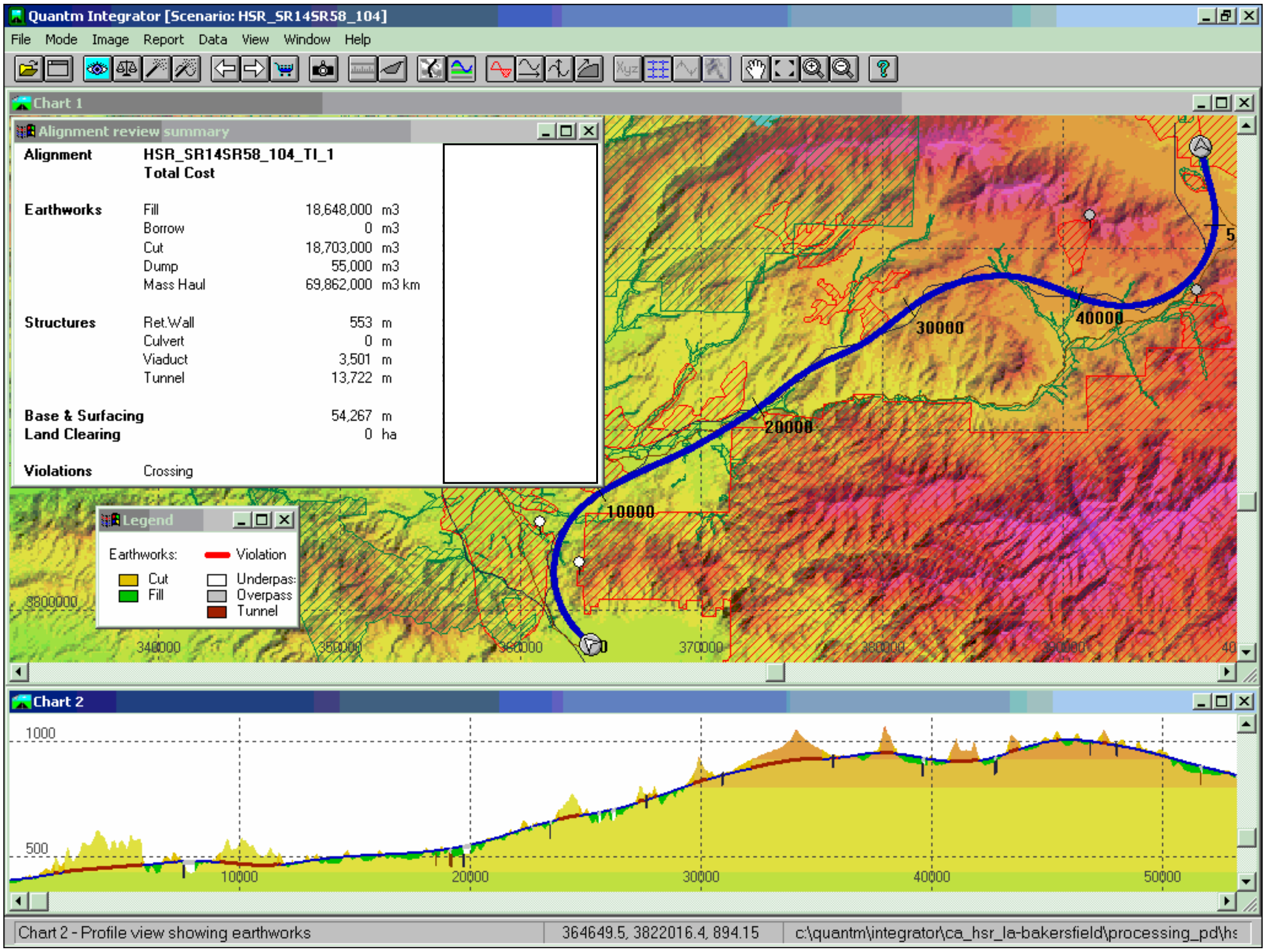

Figure S-5: SR-14 – Quantm Refined Alignment (Max. 3.5% Grade)

To avoid the potentially sensitive areas of Soledad Canyon, an avoidance alignment option was identified to the north of Soledad Canyon that would still reduce tunneling requirements as compared to the Soledad Canyon alignment option previously considered in the screening analysis. Potential environmental impacts of this alignment option will be further evaluated in the program environmental studies.

Northern Section (Lancaster to Central Valley) - The alignment options in the SR-58 corridor were refined to identify more viable options or reductions in infrastructure requirements and cost. No new, significantly different corridor options were identified. The minimum length of tunneling required through the Tehachapi Mountain crossing on the SR-58 corridor is about 5.1 miles as compared to 22 miles for the alignment options considered in the screening evaluation (at 3.5% maximum grade) and 5.8 miles for the alignment option considered in the previous corridor evaluation. Figure S-6 shows the refined alignment option. All major fault crossings can be maintained at-grade for the 3.5% maximum grade option in this corridor.

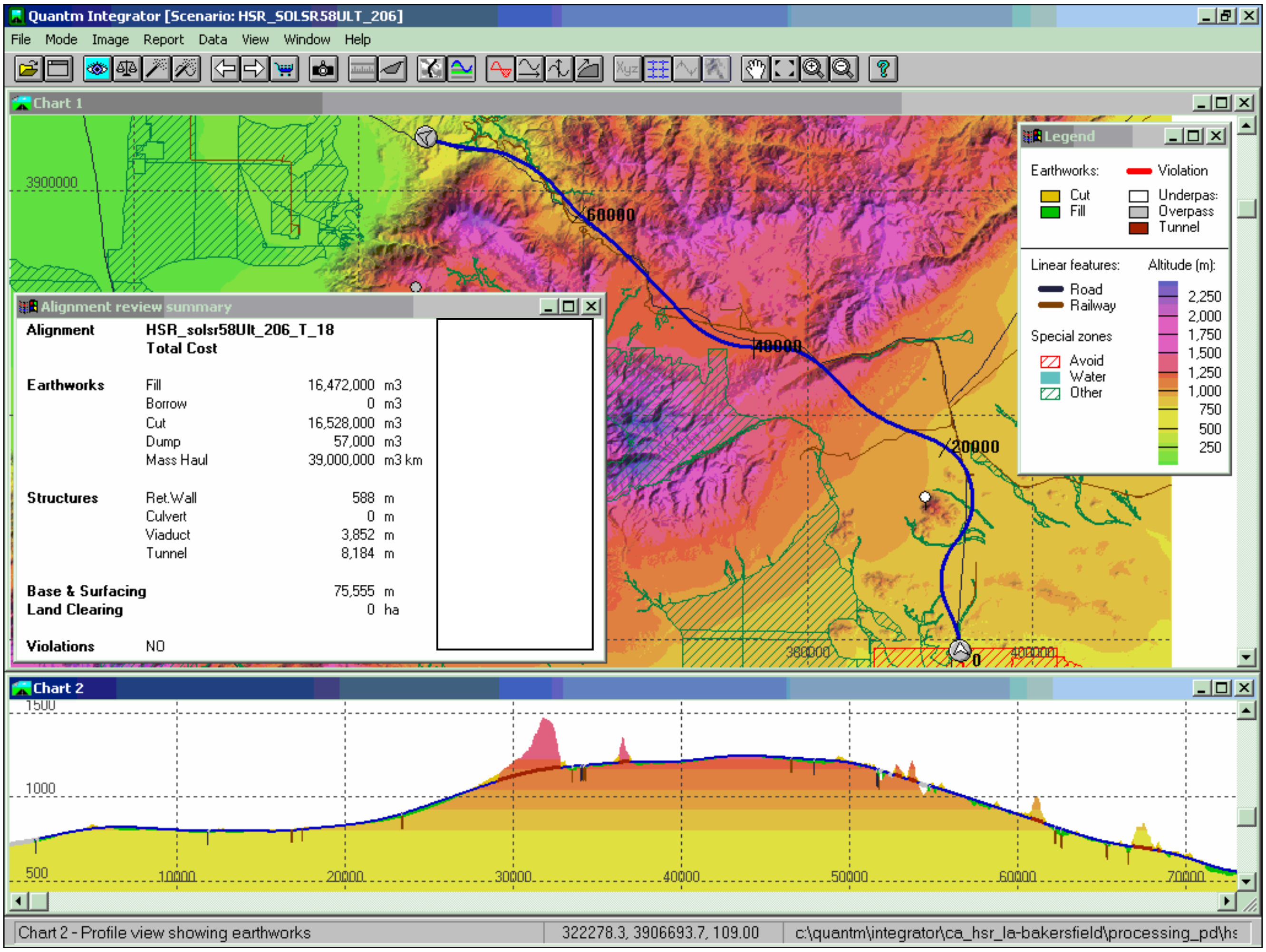

FIGURE S-6: SR-58 NORTH – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

C. SR-138/Palmdale Alignment

The southern section of this alignment is the same as the SR-58/Mojave alignment option discussed above.

The alignment and profile options through the Tehachapi Mountain Crossing were refined to identify more viable options that reduce infrastructure requirements and cost. A single tunnel segment is required for this crossing and was estimated at 14.3 miles long in the screening evaluation. The length of tunnel required on this crossing can be reduced as low as 12.8 miles at 2.5% maximum grade and to 10.4 miles at 3.5% maximum grade. Figure S-5 shows the refined alignment option at 3.5% maximum grade. No new, significantly different corridor options were identified.

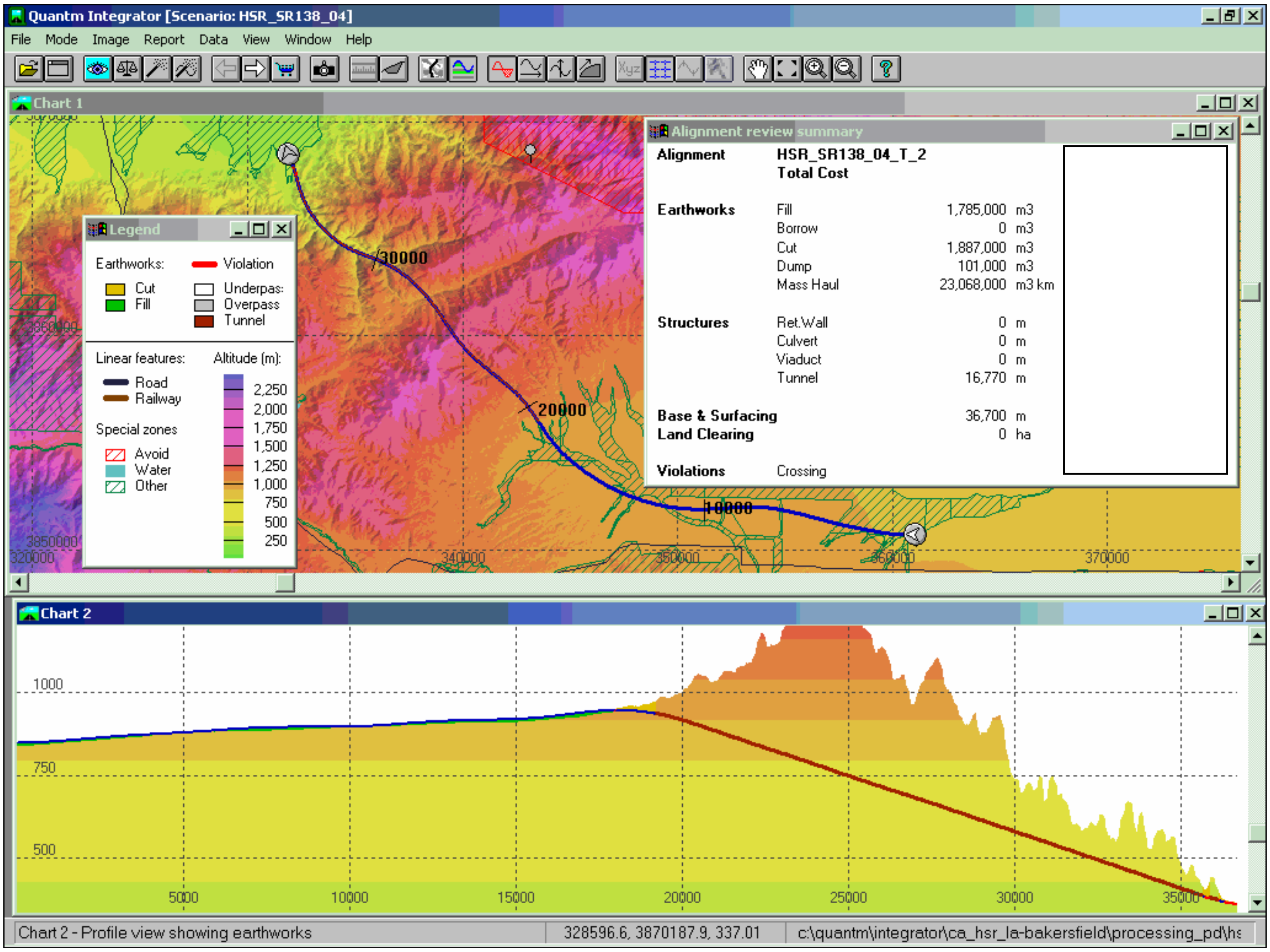

FIGURE S-6: SR-138 – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

S.4.3 Quantm System Evaluation

The study team and Authority staff concurred that the primary benefit of the Quantm system and this alignment refinement/optimization study was the confidence gained that the optimal alignment options are being considered in terms of minimizing infrastructure requirements and costs for both of the mountain crossings studied. The Authority would not have had the time or resources to identify and evaluate the broad range of potential options/variations (literally millions) through these mountain crossings and achieve this level of confidence through any other means.

Although this summary does not detail the cost estimates of the alignments produced, since further analysis and constraint definition is required, early indications are that the Quantm system will also deliver significant cost savings due to its ability to determine the optimal alignment.

This three-week study identified alignment options and refinements that significantly improved on the original alignments that had been developed in previous studies. The Quantm system was particularly applicable to the screening evaluation process. The ability to quickly test a wide range of alignment options in the context of all of the key environmental and physical constraints, as well as the main design and cost parameters was critical to achieving the objectives of this study. It became apparent that the earlier this type of comprehensive evaluation is conducted in a corridor/alignment study, the more effective the outcomes. This is particularly true in terms of providing early, accurate indications of alignment options and associated cost and potential impacts.

The ability to input new constraints to protect sensitive areas or avoid physical features was demonstrated in the investigation of the I-5 corridor where constraint zones were used to minimize the impact of crossing the fault zones, based on input from the tunneling conference. While these concerns can certainly be addressed through conventional study means, the Quantm system provided a comprehensive plan, profile and costing analysis in a very short period of time.

It is important to note that the validity of the alignments identified is highly dependent upon the comprehensiveness of the data provided/input to the Quantm system. Further, the Quantm system cannot supplant the environmental and engineering judgment that must be applied in determining the viability of the alignment options identified. The Quantm system is a powerful tool for identifying and analyzing alignment options, but it must be applied by engineering and environmental professionals within the context of all available project information.

In general, the study team confirmed that it was able to use the Quantm system as a powerful support tool to analyze a wide range of alignment options and identify beneficial refinements in remarkably short time with more flexibility to respond to specific engineering and environmental issues. The study team also confirmed that the Quantm system would be applicable to subsequent stages of the alignment development process to optimize the alignments as new constraints are defined through the further consultation and environmental analysis phases.

1.0 INTRODUCTION

In most regions of the proposed statewide high-speed train system the alignment development process is largely constrained by land use related issues (urban growth, agricultural land, existing transportation corridors, etc.) and associated environmental constraints. There are two areas of the statewide system where this is not the case; instead, the alignments and associated costs are more directly constrained by physical features (terrain, lakes, rivers, etc.) and associated environmental constraints. These areas are located in the Tehachapi Mountains between Los Angeles and Bakersfield (southern mountain crossing) and in the Diablo Mountains between the Central Valley and the San Francisco Bay Area (northern mountain crossing). While these areas have been previously studied and evaluated in terms of alignment and associated costs and impacts, screening decisions have been difficult since the distinction between alignments is often blurred due to the vast potential for variation in specific alignment (horizontal and vertical) and associated costs and impacts. Even in the areas like the Southern Mountain Crossing where the studies have focused on three primary corridors, the potential for differing alignment and grade options can present a significant difference in cost and impact in a given corridor.

Due to the potential for a wide range of alignment costs and impact within the primary corridors, the Authority has undertaken an alignment refinement and optimization effort to further clarify the screening decisions to be made on the alignment options in both the northern and southern mountain crossings. This study is intended to analyze the range of horizontal and vertical alignment options in an iterative manner to provide more confidence that the optimal alignments are being considered and more certainty concerning the cost estimates and potential impacts. This analysis of literally millions of alignment options is made possible in a relatively short period of time with the Quantm route alignment optimization and refinement system. Building on the previous work, the Program Management and Regional Study Teams worked closely with Quantm to apply their technology to analyze the alignments and will provide results prior to completing the screening process.

Figure 1-1: Regional Study Limits/Corridors

1.1 BACKGROUND

In its *Business Plan*[2] adopted in June 2000, the California High-Speed Rail Authority (Authority) recommended that the state proceed with implementation of a statewide high-speed train system by initiating the formal state and federal environmental review process through preparation of a state program-

[2] California High-Speed Rail Authority. *Building a High-Speed Train System for California, Final Business Plan*. June 2000.

level Environmental Impact Report (EIR) and a federal Tier I Environmental Impact Statement (EIS) or Program EIR/EIS. The Authority is the state lead agency for the California Environmental Quality Act (CEQA), and the Federal Railroad Administration (FRA) is the federal lead agency for the National Environmental Policy Act (NEPA). As part of the Program EIR/EIS, a number of project alternatives will be evaluated including a High-Speed Train Alternative. Within the High-Speed Train Alternative, there is a range of high-speed train alignments and station locations to be considered. To carry out the engineering and environmental work needed for the program environmental process, the state network has been divided into five regions: Bay Area-Merced, Sacramento-Bakersfield, Bakersfield-Los Angeles, Los Angeles-San Diego via the Inland Empire, and Los Angeles-Orange County-San Diego (see Figure 1-1).

For this alignment refinement/optimization study, the Merced to Bay Area and the Los Angeles to Bakersfield teams participated through providing information from previous studies, technical guidance and oversight concerning alignments, constraints and potential impacts. The Program Management Team lead the study effort coordinating with the Regional Teams, Quantm representatives and the Authority staff members.

The original work carried out on the Los Angeles to Bakersfield section was conducted using manual techniques for corridor and station screening and alignment selection. This was achieved by experienced engineers and environmental planners making visual selections from topographic maps and making educated judgments regarding optimal corridor and alignment placements. The selected alignments were then flown to obtain aerial photography and these evaluations input to a computer aided design and drafting (CADD) system named InRoads, for calculation of earthworks and alignment adjustments. Subsequent studies also included extensive application of Geographic Information Systems (GIS) to map known constraints with respect to the alignments and quantify potential impacts.

1.2 ALIGNMENT SCREENING PROCESS

In order to focus the engineering and environmental studies on the most viable routes, the Authority has undertaken an alignment screening evaluation. The purpose of the High-Speed Train Alignments/Stations Screening Evaluation is to consider all reasonable and practical options within all corridors being investigated by the Authority at a consistent level of analysis. This initial alignment and station evaluation has been accomplished through the following key activities:

- Review of past alignment and station options identified in previous studies.
- Throughout the environmental scoping process, identify alignment and station options not previously evaluated.
- Evaluation of alignment and station options using standardized engineering, environmental, and financial criteria and evaluation methodologies.
- Identification of the alignment and station options ability to attain defined objectives.

Preliminary results from the High-Speed Train Alignments/Stations Screening Evaluation for each of the regional corridors were presented to the Authority at the August 1, 2001 board meeting in San Jose and at the November 14, 2001 board meeting in Bakersfield. The technical data from these reports, combined with public and agency input has provided the Authority the necessary information to direct further studies for the Program EIR/EIS on those alignments, and station locations, and high-speed train systems which represent a reasonable range of alternatives which could attain the following objectives established by the Authority:

- Maximize Ridership/Revenue Potential
- Maximize Connectivity and Accessibility
- Minimize Operating and Capital Costs
- Maximize Compatibility with Existing and Planned Development

- Minimize Impacts to Natural Resources
- Minimize Impacts to Social and Economic Resources
- Minimize Impacts to Cultural Resources
- Maximize Avoidance of Areas with Geological and Soils Constraints
- Maximize Avoidance of Areas with Potential Hazardous Materials

The EIR/EIS must review a range of reasonable alternatives which could feasibly respond to the purpose and need for the project, or stated another way, could feasibly accomplish most of the project objectives while reducing expected environmental impacts. Public scoping meetings and consultation with other public agencies have helped the Authority to identify the potential environmental impacts to be analyzed in the EIR/EIS and to identify a broad range of potential alternatives to the proposed system.

The Alignment/Station Screening Evaluation is the process by which the Authority and the FRA will determine which alternatives should be removed from further consideration and which alternatives will receive detailed review in the EIR/EIS. This process involves reviewing the broad range of alternatives which was identified and reducing the alternatives to those that represent a range of the most reasonable and feasible means of responding to the objectives, purpose and need for the project. These are the alternatives that will receive detailed consideration in the EIR/EIS. This process also involves removing from further consideration those alternatives which, due to significant technical, environmental, and/or economic factors, would not serve to reasonably and feasibly meet the objectives, purpose and need for the proposed high speed rail system. The screening report serves to document the significant reasons for removing certain alternatives from further consideration.

The approach to screening was defined in a report titled *Alignment/Station Screening Evaluation Methodology*, May 16, 2001. Preliminary results of the screening analysis are presented in the regional alignment/station screening evaluation reports.

1.3 PURPOSE OF THIS STUDY AND REPORT

To support the alignment screening process, further alignment studies are necessary through the northern and southern mountain crossings. The purpose of this study is to further clarify and strengthen the technical basis for the screening process. The purpose of this report is to document and present the inputs, process and results of the Alignment Refinement/Optimization study. The report addresses both the technical study of alignments and the qualitative study of the Quantm system as applied to the screening level high-speed train alignments. Both aspects are described in the sections below.

1.3.1 Alignment Refinement/Optimization

The purpose of the alignment refinement/optimization study is to further clarify and strengthen the technical basis for making screening level decisions on the potential high-speed train corridors in the northern and southern mountain crossings. While these areas have been previously studied and evaluated in terms of alignment and associated costs and impacts, screening decisions have been difficult since the distinction between alignments is often blurred due to the vast potential for variation in specific alignment (horizontal and vertical) and associated costs and impacts. Even in the areas like the Southern Mountain Crossing where the studies have focused on three primary corridors, the potential for differing alignment and grade options can present a significant difference in cost and impact in a given corridor.

Due to the potential for a wide range of alignment costs and impact within the primary corridors, it is necessary to confirm and clarify the basis for the screening decisions to be made on the alignment options in both the northern and southern mountain crossings. This study is intended to analyze the range of horizontal and vertical alignment options in an iterative manner to provide more confidence that the optimal alignments are being considered and more certainty concerning the cost estimates and potential impacts. Building on the previous work, Quantm's route alignment optimization and refinement system was used for this analysis because of its capability to analyze a vast range (millions) of alignment options in a relatively short period of time.

1.3.2 The Quantm System Evaluation

The Quantm system is a relatively new technology, which is being applied for the first time in the United States as part of this effort. An evaluation of the Quantm system in terms of applicability, ease of use and quality of results is important to the system's developers as well as the Authority to the extent that the system will have continued applicability to later stages of development of the high-speed train system.

1.4 ORGANIZATION

In the chapters that follow this introduction, this report is organized into the following sections:

- *The Quantm System* - A description of the history and capabilities of the Quantm system.
- *Alignment Refinement/Optimization Process* - A description of the alignment study in terms of objectives, process, and approach.
- *Inputs and Assumptions* - A summary of the input data, design parameters, costing assumptions, physical and environmental constraints that were applied in the Quantm system to analyze the alignments.
- *Results* – A presentation of the results of the alignment refinement/optimization study including comparisons of horizontal and vertical alignments in terms of key differentiating elements such as length, length of tunnel, earthwork, length of structure and cost.
- *Conclusions* – A summary of the key conclusions reached based on the results. The conclusions are focused on those issues relevant to the screening process. Conclusions are also summarized for the application and evaluation of the Quantm system.

2.0 THE QUANTM SYSTEM

2.1 HISTORY

The Quantm system is a unique route optimization technology supported by a team that incorporates road and rail engineers, GIS technicians, mathematicians, transport researchers and system developers. It is applicable to both rail and road projects.

The system has been developed over the last 12 years by the Australian Government's research organization, Commonwealth Scientific & Industrial Research Organization (CSIRO) to specifically address the complex challenges associated with road and rail alignment selection. Initially created for the proposed Australian Very Fast Train (VFT) project in 1988, the system was tested and developed in collaboration with planners and design engineers, using real project data. In 1998, the system was used by the Speedrail consortium for the proposed Sydney to Canberra project, cutting 42% from the construction cost of the bid alignment that had been derived using the conventional planning approach.

In January 2000, the Hon. Alan Griffiths and CSIRO established Quantm Limited to maximize the commercial potential of the technology and continue its development. The Quantm system has already been widely adopted throughout Australia and New Zealand, including nine highway projects with the New South Wales Roads & Traffic Authority. The system received an Australian Technology Award in 2001 in recognition of its contribution to reducing the cost of infrastructure in Australia and the Queensland Department of Main Roads was so impressed at the results achieved by its planners that it presented a paper on the Quantm system at the IRF 14th Road World Congress in Paris in June 2001.

2.2 TECHNOLOGY

The Quantm system is an automated route selection and optimization tool. It carries out automated alignment searches and corridor screening based on the terrain, geology, geometry, constraints and unit costs defined by the project planner.

2.2.1 The Conventional Approach

The current conventional practice for alignment identification selection is essentially a manual function. The designer/planner uses intuitive skill and experience in selecting a route, using Computer Aided Drafting and Design (CADD) technology such as InRoads to determine quantities and costs and supporting the planning process.

CADD systems have been developed primarily for detailed design and rely primarily upon the planner to place the alignment. This process is slow, thus limited in terms of the number and extent of alignment investigations.

GIS is specifically designed for storing, arranging and displaying spatially keyed data. It is an excellent tool for working at the macro level, identifying sensitive areas and providing an indication of corridor alternatives (in the horizontal plane only). It is not, however, a tool for corridor/alignment optimization. While some GIS packages can be used to identify corridors where alignments are likely to be cheaper by weighting the 'non-cost' constraints such as social and environmental constraints, they do not consider:

- Terrain (GIS operates in horizontal plane only)
- Geometric constraints
- Crossing of linear features
- Cost data

GIS cannot determine alignment construction costs or define the alignment and construction cost impact of new constraints as they arise through the consultation phase.

2.2.2 The Quantm Approach

With Quantm, millions of alignments are considered and costed before the system delivers a range of low cost alignments that endeavor to meet the defined constraints, to the planner for review. The speed of the system actively encourages the investigation of alternative scenarios and sensitivity analyses, enabling the planner to determine the best alignments for the project.

Front-end software called Quantm Integrator is installed on the planner's Personal Computer (PC) along with the digital terrain data that has been converted into the Quantm format. The terrain data is also installed on Quantm Pathfinder – the optimization engine in Melbourne (see Figure 2-1).

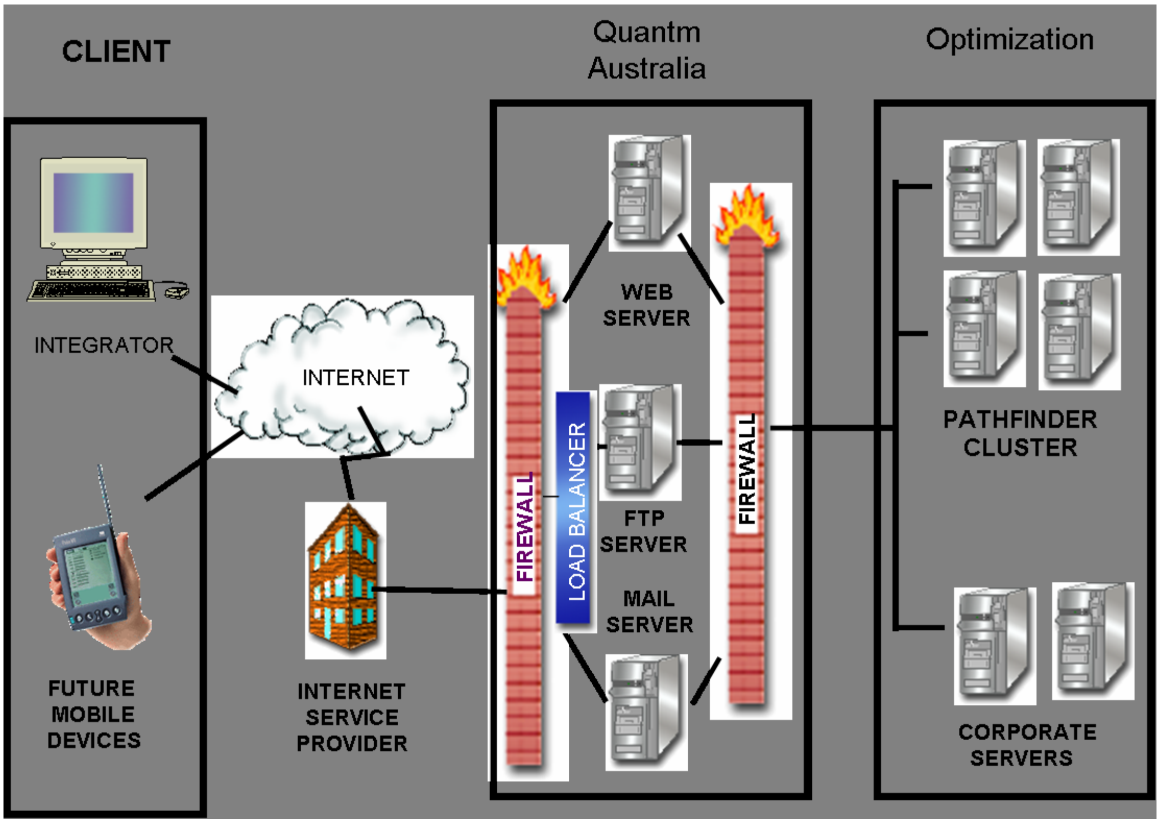

FIGURE 2-1: FLOWCHART (THE QUANTM SYSTEM OPERATES WITH INTEGRATOR ON THE PLANNER'S PC, LINKED TO THE OPTIMISATION ENGINE, PATHFINDER VIA THE INTERNET)

The skilled planner then inputs all of the data relevant to the project including all known constraints, environmental issues, heritage issues, social issues, linear features, geology and cadastral boundaries (if available). These zones can be defined by simply transferring existing digital data (i.e. GIS format) or manually input using drop down menus and a 'point and click' approach. The planner can also input all of the cost drivers for the particular construction such as cut, fill, haulage, borrow, spoil, bridges and tunnels as well as defining of the design parameters such as maximum grades, minimum curve radii, benches and batter slopes.

On completion of the data input and definition of the start and end points for the route, the scenario file is sent, via the Internet, to Quantm Pathfinder for optimization. Within hours, a range of 'best option' alignments that meet the defined constraints are returned to the planner for review. The planner can analyze and compare the location, cost, earthworks, grades, curves and environmental impact of each alignment. The alignments can be viewed on a terrain model, relief map or overlaid on aerial or satellite photography (if available).

The Quantm system is applicable to both the strategic planning/corridor scoping and detailed planning stage that involves public consultation and environmental assessments. The ease of use and speed of the system means that new constraints that arise during the consultation process can be defined within minutes and the scenario file resubmitted to Pathfinder in an iterative process shown in Figure 2-2.

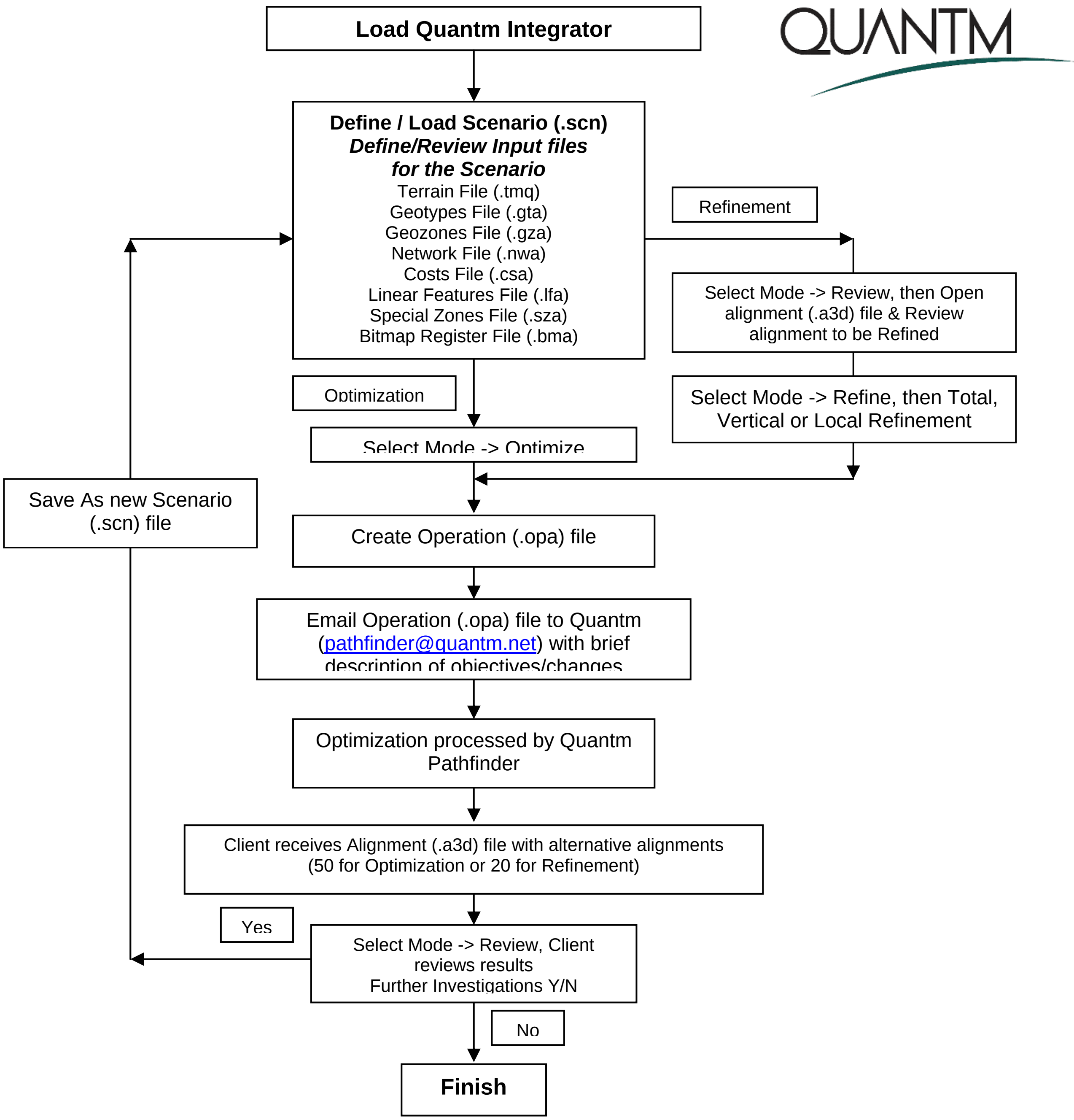

FIGURE 2-2: QUANTM INTEGRATOR FLOWCHART

Within hours, the planner will receive a re-optimized set of alignments that meet the new constraints. This liberates the planner to conduct comprehensive sensitivity analyses to determine the alignment and construction cost impact of changes to grades, curves and special treatment zones.

On completion of the planning process, the planner can simply transfer Quantm output into the preferred CADD system for detailed design work. If new constraints are identified during the design phase, it is a simple process for the planner/designer to flip the CADD alignment back into Quantm for re-optimization.

2.2.3 Features

Quantm operates in three modes:

- *Optimization* mode is broad corridor screening which can be applied to wide terrain corridors and focused in particular directions by the positioning of guide points;
- *Refinement* is intense optimization within a narrow band commencing with a seed alignment. The seed alignment can be derived from a Quantm optimization or imported from an external source such as InRoads; and
- *Realignment* mode allows the planner to lock onto an existing alignment with the system only departing from it when the demands of new geometric standards, physical constraints or cost economies dictate.

Quantm has the capability to rapidly generate alignments for each scenario defined, enabling the planner to:

- Identify low-cost alignments that meet the defined constraints
- Determine the initial preferred corridor/alignment in a fraction of the time currently required
- Demonstrate respect for the community and the environment by undertaking comprehensive assessment of alternative alignments as new constraints are defined
- Produce forecast quantities and costs very early in the project development process;
- Evaluate alignments derived using the conventional planning approach;
- Carry out extensive sensitivity analysis to determine the alignment and cost impacts of changes to geometric standards and the addition/amendment of constraints.
- Produce reports and displays that can support the consultation process
- Utilize digital data created in GIS/CADD formats; and
- Export the center string into CADD for detailed design or to utilize visualization capabilities

3.0 ALIGNMENT REFINEMENT/OPTIMIZATION PROCESS

The alignment refinement/optimization process encompassed the following activities including establishing clear objectives for the study, establishing a study team to complete the task, training the study team on the Quantm system, and systematically applying the Quantm system to each corridor considered to achieve the objectives.

3.1 STUDY OBJECTIVES

Several objectives were established to guide the alignment refinement/optimization study in both the northern and southern mountain crossings as follows:

- To confirm the general corridors considered in the screening studies to date and/or identify any other corridors of equal or greater viability that may have been overlooked in previous studies.
- To refine the alignment options in each general corridor to identify the most viable options in terms of infrastructure requirements and impact minimization.
- To test the sensitivity of the alignment options in each corridor to key defining criteria such as vertical grade, alignment geometry, infrastructure (tunnel, structure) costs and key environmental constraints.

Achieving these objectives in each of the corridors considered will provide the Authority with a high level of confidence in the alignment options considered and their associated costs and impacts and a stronger technical basis for alignment screening decisions.

This study was originally scoped to address only the southern mountain crossing. Based on the findings of the Tunneling Conference, which was held on December 3, and 4, and initial results from the Quantm analysis of the southern mountain crossing, the Authority recognized the need for further investigation of alternatives for the northern mountain crossing. Additional funds were identified, and a subsequent agreement was reached to use the Quantm tool to also address the northern mountain pass.

3.2 STUDY TEAM

A study team consisting of representatives of Authority staff, the Program Management team, the Los Angeles to Bakersfield and the Merced to Bay Area Regional Study Teams as shown in Table 3-1. was formed for this study. Quantm trained the team in the operation of the software and guided the initial runs over a two-week period from November 26th 2001. The project was controlled from the offices of Parsons Brinckerhoff in Orange County, California and inputs and outputs sent and returned by email to Quantm's central processing facility in Melbourne, Australia.

TABLE 3-1: STUDY TEAM

Name/Title	Organization	Study Role
Dan Leavitt / Deputy Director	California High-Speed Rail Authority	Oversight
Carrie Pourvahidi / Deputy Director	California High-Speed Rail Authority	Oversight
Kip Field, PE / Project Manager	Program Management Team / Parsons Brinckerhoff Quade & Douglas, Inc.	Management
Clint Herrera, PE / Civil Engineer	Program Management Team / Parsons Brinckerhoff Quade & Douglas, Inc.	Application/ Engineering Evaluation

Name/Title	Organization	Study Role
Scott Larsen / GIS / Environmental Constraints	Program Management Team / Parsons Brinckerhoff Quade & Douglas, Inc.	Application/ Environmental Evaluation
Sylvia Salenius AICP/ Project Manager	Los Angeles - Bakersfield Regional Team / P&D Consultants	Regional Input/Guidance
Rachel Vandenberg, PE / Engineering Team Manager	Los Angeles - Bakersfield Regional Team / DMJM+Harris	Regional Input/Guidance
Duane Haselfeld / Biologist/GIS Specialist	Los Angeles - Bakersfield Regional Team / Psomas Associates	Application/GIS Constraints
Bruce Hilton, RG / Geologist	Los Angeles - Bakersfield Regional Team / Kleinfelder	Regional Geologic Input
Shelley Austin / Biologist	Los Angeles - Bakersfield Regional Team / P&D Consultants	Regional Biology Input
Dave Mansen / Project Manager	Merced to Bay Area Regional Team / Parsons Transportation Group	Regional Input/Guidance
Neal Mace / Geologist	Merced to Bay Area Regional Team / Geotechnical Consultants, Inc.	Regional Geologic Input

3.2.1 Training

The Quantm system is new to the United States and all of the consultant teams currently working on the high-speed train program. A training process was required to familiarize the Authority's staff and consultants with the Quantm system in a short period of time and move quickly into the application of the product for the corridors defined. A five-day comprehensive course was planned at the offices of Parsons Brinckerhoff in Orange, California to train the study team to operate the system, define data sets, create constraints and review alignments and profiles produced by the system. The course was planned to include three days intensive training followed by two days solo-operation of the system with on site support from Quantm. Quantm provided two trainers. As the training commenced, Quantm and the study team identified the need to modify the training approach to focus more on specific application of high-speed train alignments, using the actual corridor studies to provide the context for a more "on the job" training approach. Quantm extended the time period of their involvement to span three-weeks to also address the northern mountain crossing. During that time significant progress was made on the alignment refinement and optimization process. Training became the secondary issue and was accomplished throughout the three-week period.

3.3 CORRIDORS CONSIDERED

3.3.1 Southern Mountain Crossing - Tehachapi Mountains (Bakersfield to Sylmar)

Three primary corridor alignments are being considered through the Tehachapi Mountains: I-5 – Grapevine, State Route 58 (SR-58), and the Aqueduct/State Route 138 (SR-138). Numerous specific alignment options have been considered in each of these three general corridors. Currently, alignments have been developed considering two grade options representing a range of cost and train performance: a 2.5% maximum gradient to optimize train performance and reduce lifecycle operations and maintenance costs and a 3.5% maximum gradient to minimize tunneling and associated infrastructure costs. The Quantm system was also applied to identify the potential infrastructure requirements and cost associated with 5% maximum grades for comparative purposes. Based on previous studies, the Authority adopted a maximum sustained grade of 3.5% for the planning and engineering of the high-speed train system. Others have suggested that 5% maximum gradient is feasible.

As part of an extensive peer review of its previous studies and conclusions, the Authority sought comment on the viability of the 5% grades from three sources: Japan Railway Technical Service (JARTS) - the technical consulting division of Japan Railways, SNCF International (SNCF) - the French National Railways, and DE Consult (DEC) - the technical consulting division of the German National Railways. Based on the previous studies and the results of the peer reviews the Authority concluded that maximum grades of up to 5% are technically feasible; however, they are not economically or operationally viable due to the high energy requirements and inability of equipment to maintain high speeds over sustained segments of grades over 3.5%. The implications of these grades on performance would be further complicated by the expectation of 220 mph maximum speed capabilities and the ability to meet federal safety requirements. The higher maximum grades would adversely impact the capability to operate medium weight (specialized) freight services on the high-speed lines when passenger services are not operating. A key factor in the past decisions to limit the maximum grade is the fact that 5% grades have yet to be tested in revenue service. Furthermore, no existing high-speed train operator plans to implement new lines with 5% grades. The 3.5% gradient is accepted as the practical limit for sustained grades on HSR systems throughout the world. Grades greater than 3.5%, up to 5%, can be considered for short segments, if the following related issues are evaluated and mitigated: impact on operations, cost and availability of special equipment required, safety and reliability of the system, and the impact on the trackbed or infrastructure.

The current study alignments are described in general below. Figure 3-1 illustrates the primary alignments and Figures 3-2 and 3-3 show the 2.5% and 3.5% profile grade options produced in the screening analysis to date.

A. I-5/Grapevine Alignments:

Interstate 5 (I-5) Alignment: This alignment would extend east along the Union Pacific Railroad (UPRR) from a Bakersfield station, south along State Route 184 (SR-184)/Wheeler Ridge Road, and generally follow I-5 over the Tehachapi Mountains through Santa Clarita to Sylmar.

I-5 Alignment via Comanche Point: This alignment would extend east along the UPRR from a Bakersfield station, south along SR-184, then south-southeast to Comanche Point along an existing power easement, tunneling from Comanche point to the I-5 alignment, then generally following I-5 to Santa Clarita and Sylmar.

B. State Route 58 (SR-58) / Mojave Alignment:

Following SR-58 east from Bakersfield, generally following SR-58 through the Tehachapi Mountains to Mojave, along UPRR through Antelope Valley, through Soledad Canyon or along State Route 14 from Palmdale to Santa Clarita and generally following State Route 14 (SR-14) from Santa Clarita to Sylmar.

C. Aqueduct Alignment / State Route 138 (SR-138):

Alignments parallel to SR-138 were developed as a variation of the prior alignment that paralleled the California Aqueduct from the Tehachapi crossing to Palmdale. This SR-138 alignment would extend east along the UPRR from a Bakersfield station, south along SR-184, then south-southeast to Comanche Point along an existing power easement, tunneling under the Tehachapi mountains near the California Aqueduct, then veering to the east along SR-138 to the UPRR, through Soledad Canyon or along State Route 14 from Palmdale to Santa Clarita and generally following SR-14 from Santa Clarita to Sylmar.

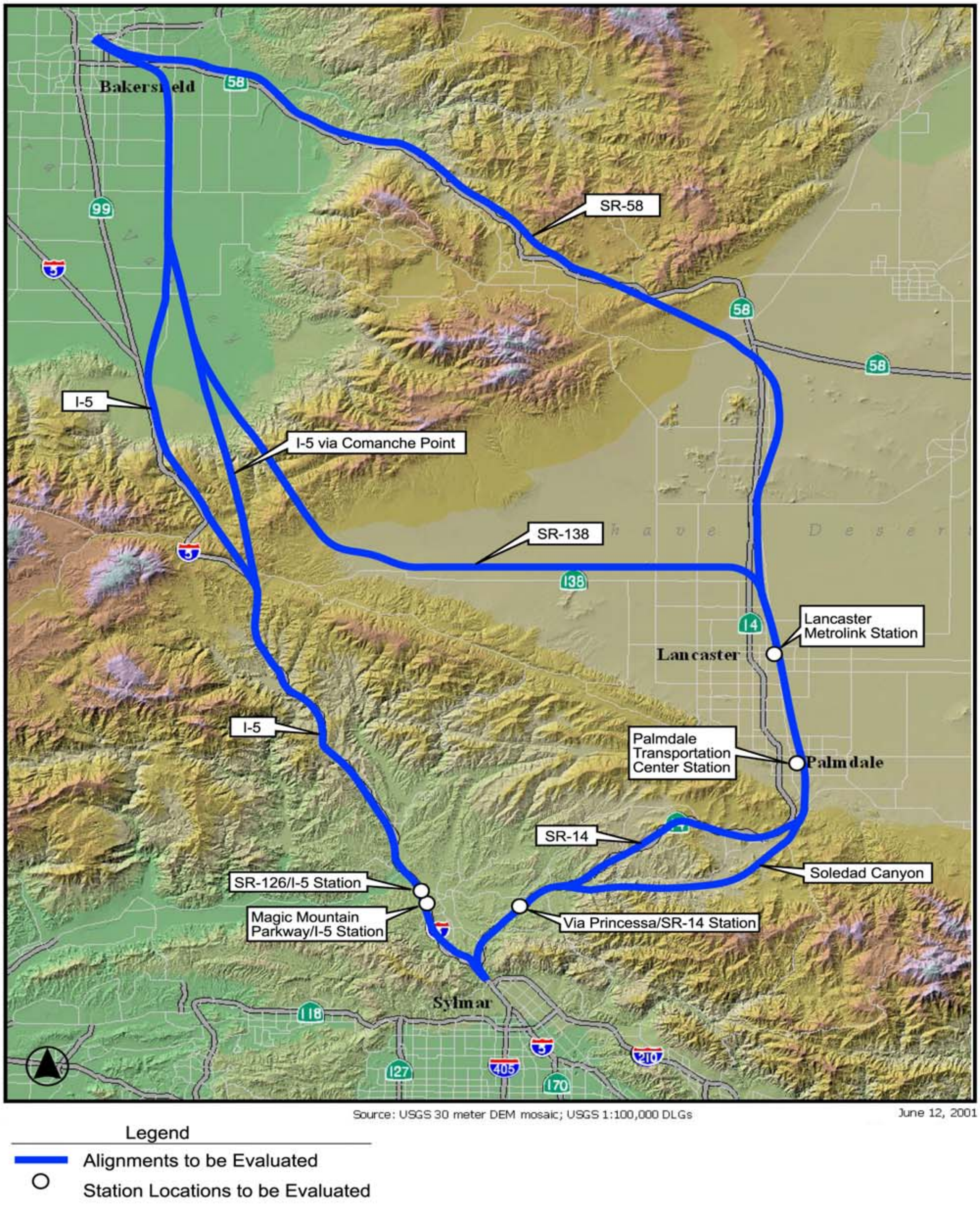

FIGURE 3-1: ALIGNMENTS AND STATION LOCATIONS TO BE EVALUATED BAKERSFIELD-TO-SYLMAR SEGMENT

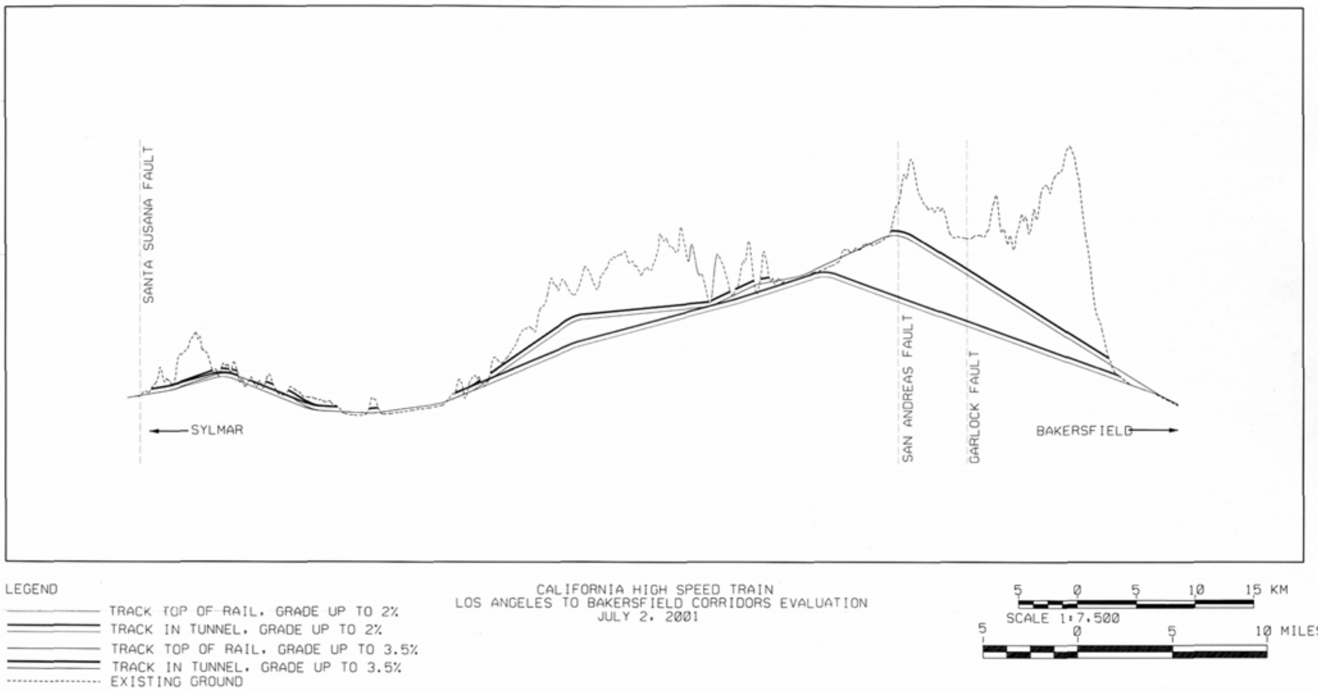

FIGURE 3-2: 2.5% AND 3.5% MAXIMUM GRADE OPTIONS – I-5/GRAPEVINE ALIGNMENT OPTION

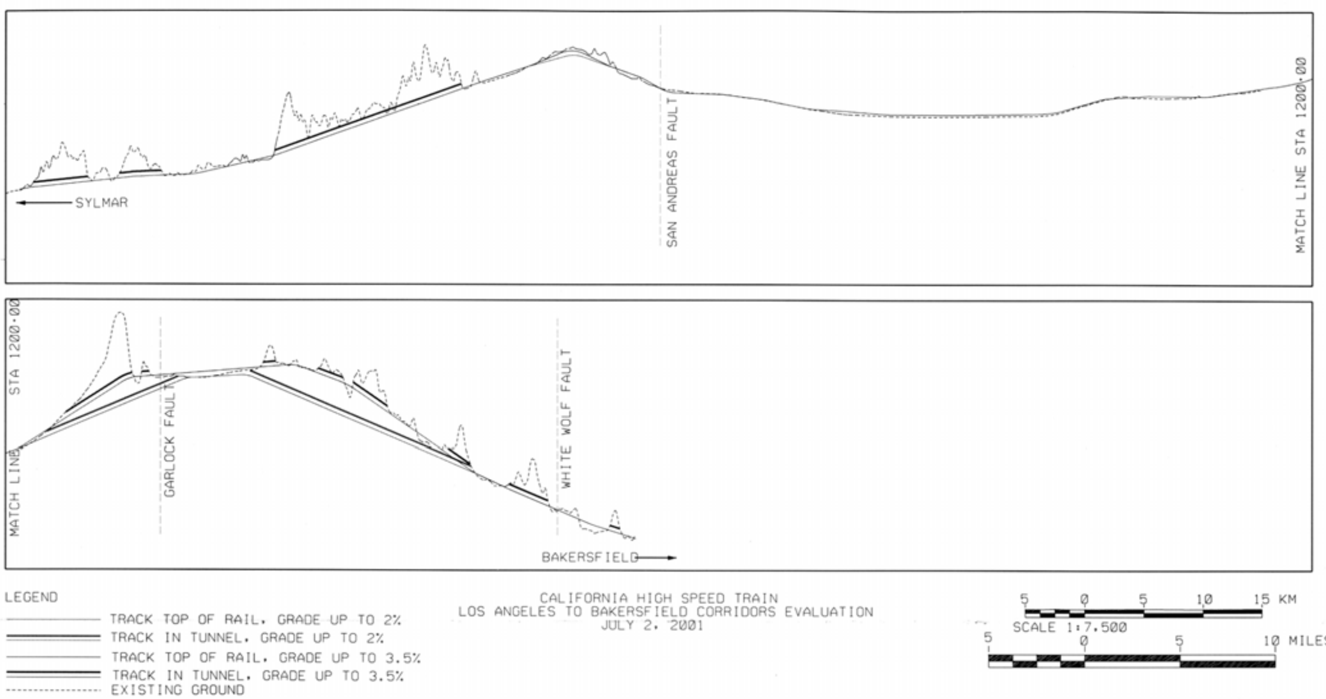

FIGURE 3-3: 2.5% AND 3.5% MAXIMUM GRADE OPTIONS – SR-58 ALIGNMENT OPTION

3.3.2 Northern Mountain Crossing - Diablo Mountains (Merced to San Jose)

The following alignment options are currently being evaluated for the Merced-to-San Jose Segment. The northern alignment would involve construction of a 31-mile tunnel (49.6 km) that would be among the longest in the world though difficult mixed soil and geology types. The Pacheco Pass alignments would be mostly at-grade and would require substantially less tunneling; possibly as little as 12 miles with no single tunnel exceeding 6 miles in length. The Quantm system was applied to identify the potential infrastructure requirements and cost associated with alignment options using 3.5% and 5% maximum grades for comparative purposes. The alignment options are described below and illustrated in Figure 3-4. *The Quantm study does not differentiate between Options B and C. Instead, it focuses on the Pacheco Pass portion of those alignments.*

A. Direct Tunnel Northern Alignment (Northern Crossing):

This alignment would have a station at the existing San Jose (Diridon) Station heading south on the Caltrain/UPRR, just north of I-85 turning east into a 31-mile long (49.6 km) tunnel to San Joaquin Valley to Merced (near Castle Air Force Base). There would be no intermediate stations between San Jose and Merced.

B. Caltrain/Gilroy/Pacheco Pass Alignment (SR-152/Pacheco Pass):

This alignment would extend south along the Caltrain/UPRR rail corridor through the Pacheco Pass and then the San Joaquin Valley to Merced.

C. Morgan Hill/Caltrain/Pacheco Pass Alignment (SR-152/Pacheco Pass):

This alignment would extend south along the Caltrain/UPRR rail corridor through the Pacheco Pass and San Joaquin Valley to Merced.

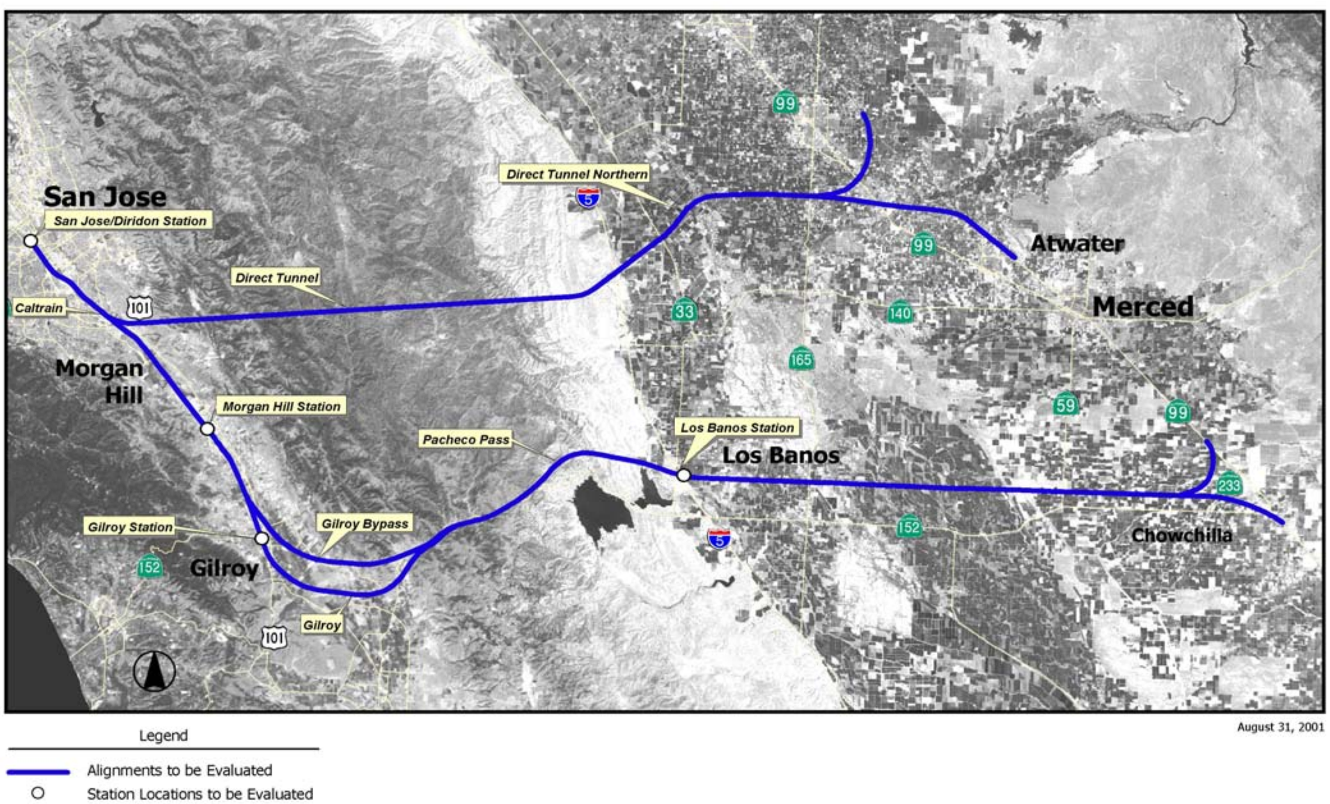

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FIGURE 3-4: ALIGNMENT AND STATION LOCATIONS TO BE EVALUATED MERCED TO SAN JOSE SEGMENT

3.4 APPROACH / METHOD

The study team used the Quantm system to investigate a range of alignments using the optimization and refinement functions.

3.4.1 Optimization

The optimization function instructs the system to investigate the full area of the digital terrain map (or pre-defined corridor) to determine optimal alignments that meet the constraints defined by the study team. The system then costs and considers approximately 12 million alignments for each scenario submitted before delivering the 50 lowest cost alignments to the planner for review. Figure 3-5 provides an example of multiple corridors identified by the Quantm system for the I-5.

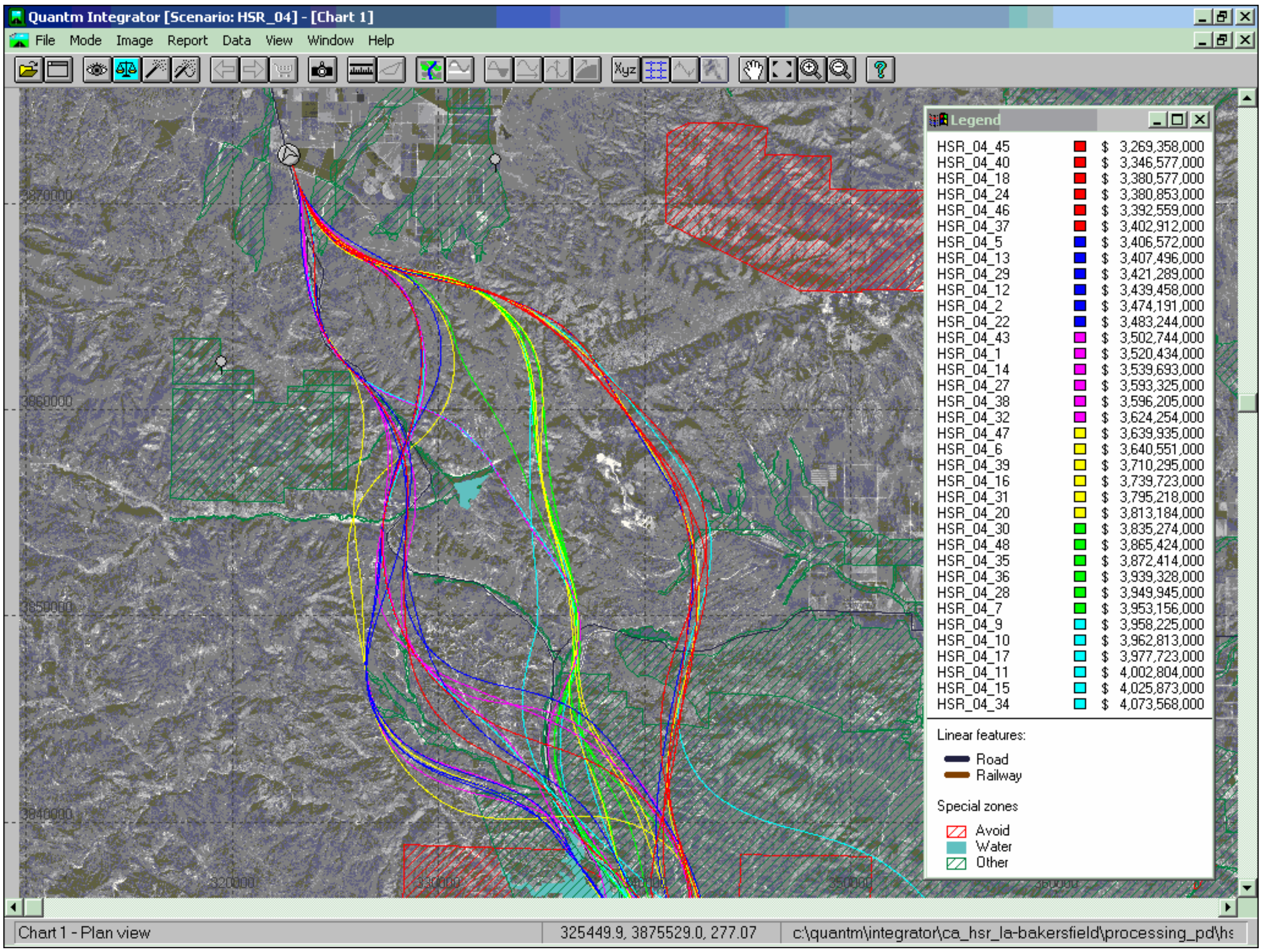

FIGURE 3-5: I-5 MULTIPLE ALIGNMENTS DISPLAYED OVER AERIAL PHOTO / SATELLITE IMAGE

This function allowed the study team to investigate whether the optimal corridors for the I-5, SR-58 (North and South investigations) and the SR-138 had been identified and to consider alternative alignments outside of those corridors previously defined. Figure 3-6 refers to SR-58 south and displays the Original Alignment (black alignment), the Quantm refinement of that seed (red alignment) and those alignment options identified from the Quantm optimization.

The value of this function was demonstrated on the I-5 investigations regarding crossing of the fault zones to the east and west of the Original I-5 alignment. Previous alignment options in this corridor were limited to the extent they avoided or mitigated this issue. The study team applied this function to explore alternative alignments to the north of the Pacheco Pass direct tunnel option. This demonstrated that alignments are available that meet the defined constraints, of max. 3.5% grade and maximum single tunnel length of 6 miles, and pass close to the existing SR-130. It is anticipated that the SR-130 will be used as an access road for tunneling and heavy construction machinery.

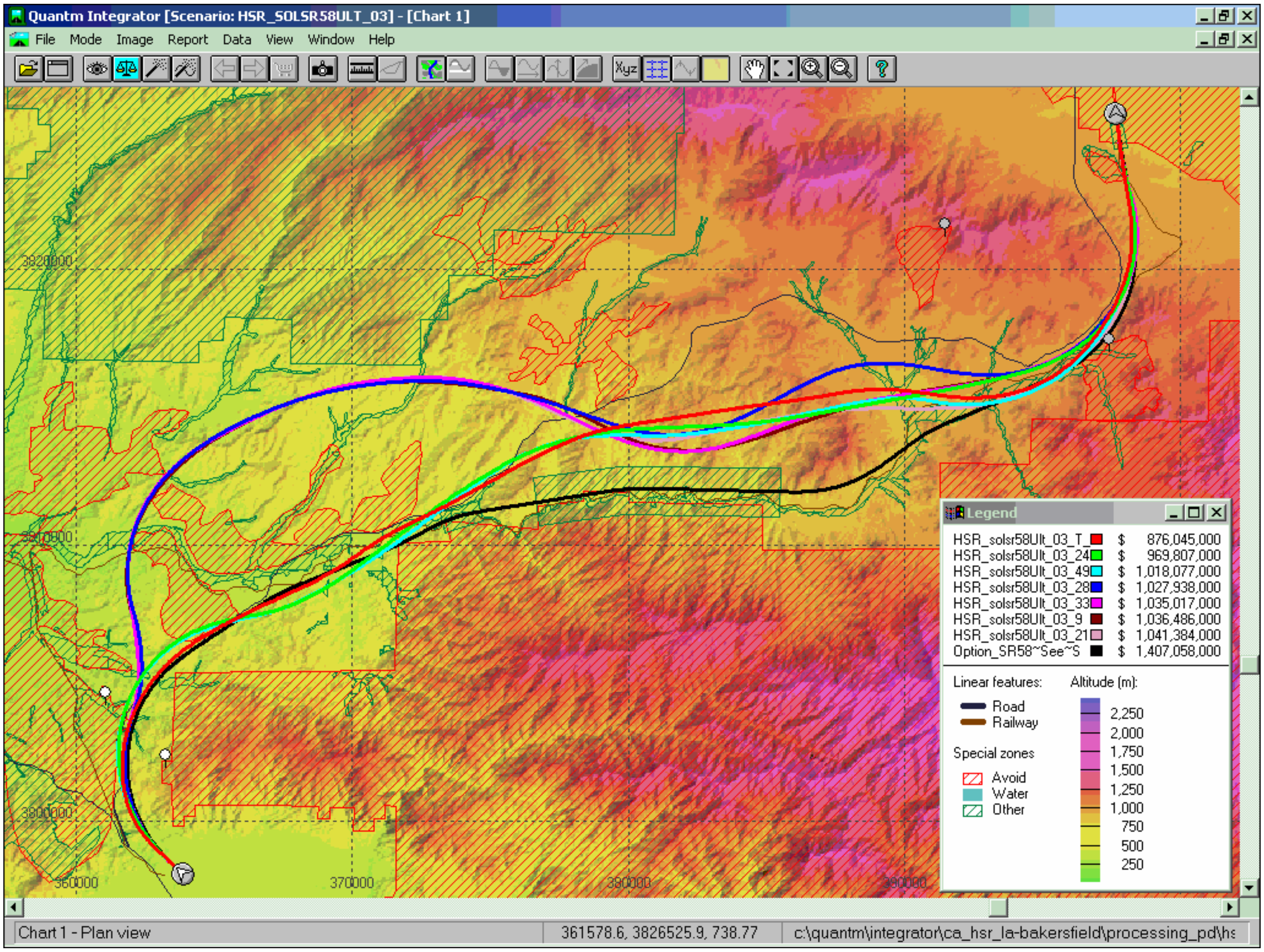

FIGURE 3-6: SR-58-SOUTH – QUANTM ALIGNMENTS DERIVED FROM OPTIMIZATION AND REFINEMENT RESULTS (MAX. 3.5% GRADE)

3.4.2 Refinement

The refinement function instructs the system to carry out a comprehensive assessment of alternatives in a focused area, narrowing the search to a defined corridor. The seed for the refinement can be derived from a Quantm optimization or imported from an external source such as InRoads.

The study team used this function to investigate alternatives in the vicinity of the pre-determined Pacheco Pass, I-5, SR-58, SR-14 and SR-138 corridors. This function was also applied on the alignments identified by the Quantm optimization east of the I-5 corridor, to refine the at-grade crossing of the fault zones.

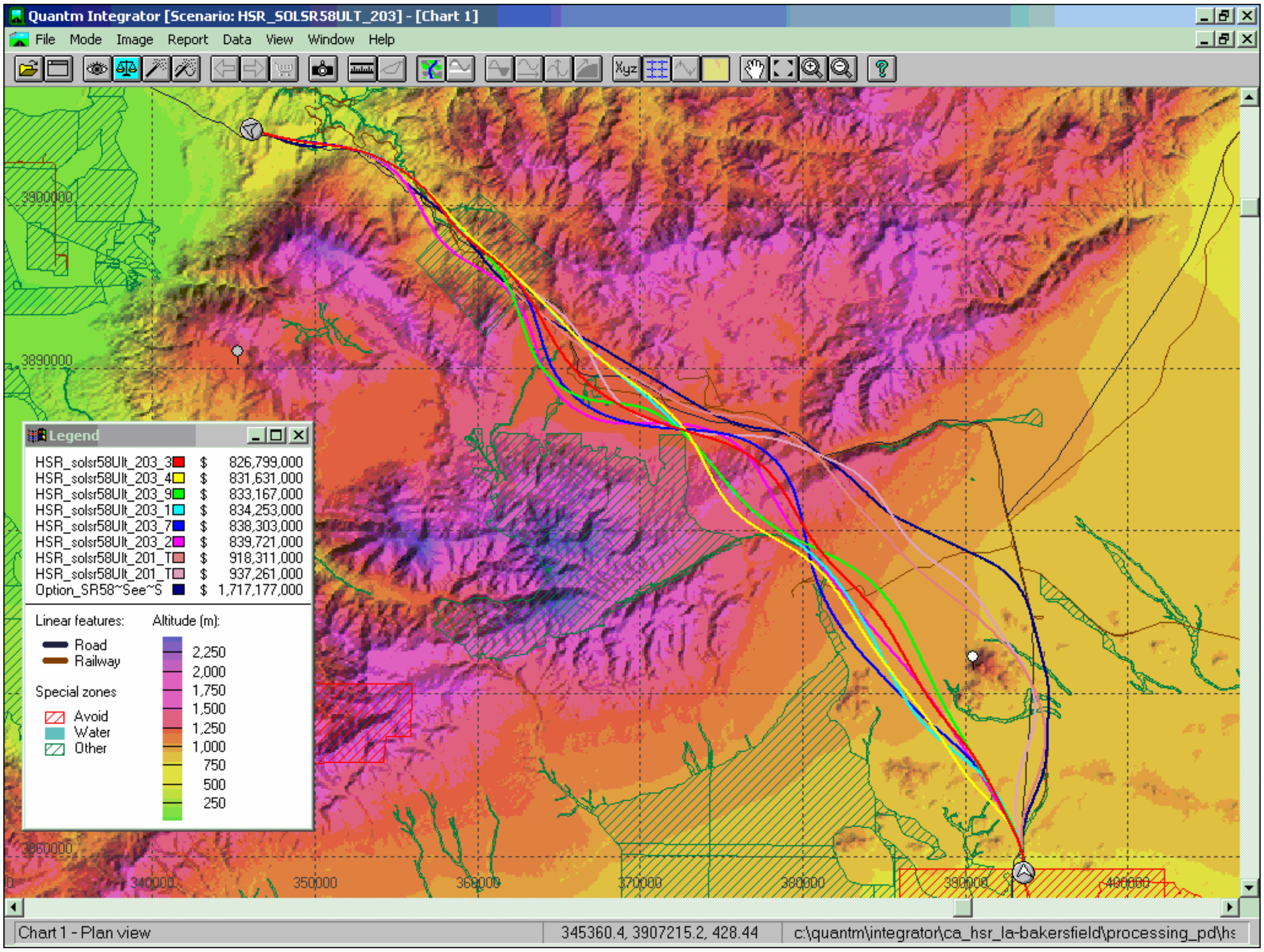

FIGURE 3-7: SR-58-NORTH - TOTAL REFINEMENT (MAX. 3.5 % GRADE)

3.4.3 Using Special Treatment Zones

The Quantm system allowed the study team to define special treatment zones to protect sensitive sites, control areas of investigation or establish different rules/costs for crossings of defined zones.

This function was used on a number of areas, including the:

- Pacheco Pass study where a zone was created as an avoidance alternative protecting the Henry W. Coe State Park by forcing the alignment to cross in tunnel. This is demonstrated in Figure 3-8.
- I-5 study where an avoid (no-go) zone was defined to force investigation to the west of the existing corridor, with a single crossing of the fault zone

- I-5 study where a geometric zone was created to increase the cost of major structures crossing the fault zone to reflect increased construction cost and to encourage the system to identify alignments that cross at-grade and do not follow the fault zone.
- Tehachapi Pass study where flood plain and other sensitive areas were defined to instruct the system to keep the alignment above the natural surface.
- SR-58 where no-go zones were created to constrain the alignment to the existing rail corridor through Palmdale and Lancaster.

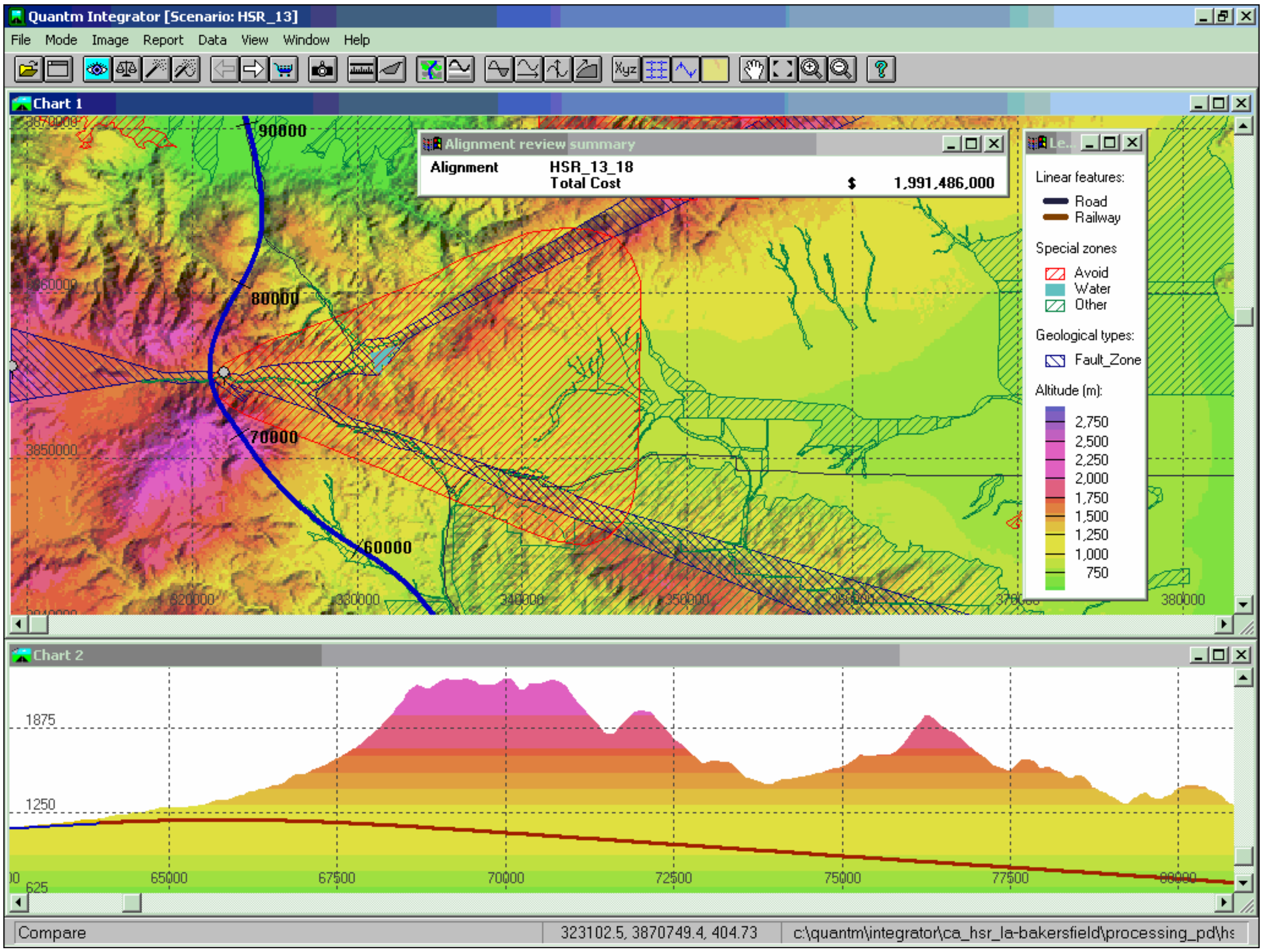

FIGURE 3-8: I-5 STUDY UTILIZING SPECIAL TREATMENT ZONES TO GUIDE THE ALIGNMENT AND REFLECT ADDITIONAL COSTS ASSOCIATED WITH FAULT ZONE CROSSINGS

3.4.4 Varying Geometric Standards for Sensitivity Analysis

The study team used the system to consider the alignment and construction cost implications of varying the maximum grade between 2.5% and 3.5% as well as initial tests of 5%. While this approach has not been exhaustively utilized to date, the initial applications demonstrated the ease and speed of this process.

4.0 INPUTS AND ASSUMPTIONS

4.1 TERRAIN DATA / MODEL

Available terrain data was converted into Quantm format by Quantm's technical team and the study team over a period of 3 days from November 26th to 28th. The data compiled during this period would form the basic platform for first stage Quantm corridor screening and optimization studies. The terrain data for the corridor screening studies was based on GIS data from the United States Geological Survey (USGS) at 5-meter contour intervals. This terrain data was provided from existing USGS Digital Elevation Model (DEM) data available in Geographic Information System (GIS) ArcView format in the Universal Transverse Mercator (UTM) coordinate base and provided in an ASCII format for conversion to the Quantm terrain model format.

Environmental data was also available in ArcView format. This data was provided in the universal Drawing Interchange Format (DXF) and converted to linear feature and special treatment zone constraints in Quantm Integrator format via simple conversion tools by Quantm's technical team. The study team was also able to create constraints within their CADD systems, InRoads and MicroStation, for conversion using Quantm's conversion tools.

4.1.1 Spot Aerial Imagery:

10-meter resolution aerial imagery was provided by CNES/SPOT Image Corporation. It was taken from 1998 to 2000 and is black and white. This image was used during the alignment optimization and helped depict both natural and environmental constraints. The aerial image was particular useful in this situation to help locate urban areas and existing structures.

4.1.2 Digital Elevation Model (DEM)

A 30-meter resolution digital elevation model (DEM) was provided by the study team. A DEM is a terrain model created by the USGS that gives arbitrary elevations at 30-meter intervals for locations throughout the study area. This file was then converted to an ASCII file containing x, y & z coordinates for ultimate conversion to a Digital Terrain Model (DTM). Once the DTM was inserted into the Quantm system it could be viewed as a shaded relief model showing the various topological features for the study area. This model is georeferenced and allows the user to get a feature elevation for any area on the Terrain Model.

4.2 GEOLOGY

Information regarding major geologic features was provided and used to define special constraint zones. This included major seismic faults and landslide areas. At this level of study no information is available regarding geologic strata at various depths. Thus, a single geologic zone was created as a default and was associated with basic infrastructure and earthwork costs. However, an example of how this feature may be used during further studies is the insertion of zones to reflect the higher cost of major structures required to cross the San Andreas Fault zone. Input from the Tunneling Conference conducted on December 3-4 was useful to define these major cost items.

Stratum characteristics of batter slope, bench width, extraction costs and suitability for use as fill were ignored to remain consistent with the studies to date that assumed a general 2:1 slope for all required cuts and fills where corridor width was not limited. However, when selected or preferred corridors are identified, more detailed geological data may be obtained and input to the system for further refinement/optimization of alignments.

4.2.1 Cuts and Fills

The previous estimate of $7.00 per cubic meter of earthwork (cut and fill) was expanded to take account of borrow, spoil and mass haul as follows:

Cut	$7.00 per m3
Fill	$6.75 per m3
Borrow	$10.25 per m3
Spoil	$8.00 per m3
Haul	$0.25 per m3/km

The system allows for multiple geological types and geological zones to support the planning process as geotechnical surveys are undertaken and more comprehensive data obtained. This includes limitless strata types, each with associated earthworks costs, batter slopes and bench widths.

4.3 ALIGNMENT GEOMETRY

Start and Finish points for each alignment option were input as x, y & z coordinates along with bearing and grade to link with either existing infrastructure or proposed works.

Other geometric data defined also included:

Vertical Grades: minimum and maximum absolute grades 2.5% and 3.5%

Cross Section: width of formation in cut - 19.3m and fill - 15.3m

Horizontal and Vertical Curves: minimum horizontal radii - 4750m, minimum vertical radii - 48000m for crests and 32000m for sags

Existing Alignments (derived during previous studies) were input to the Quantm system from InRoads via 3-dimensional MicroStation DGN format. These alignments were used to compare Quantm derived alignments against those previously derived using conventional practice. The initial objective was to input unit costs and define various constraints that accurately reflected the assumptions that had been made in the derivation of these alignments.

4.4 COSTS OF MAJOR STRUCTURES

Unit costs for the major structures were defined as follows:

Retaining walls – Retaining walls are included automatically if the cross slope is too steep, i.e. steeper than the required batter for each geological type. Although the cost of retaining walls are able to be defined as a combination of linear cost, which may represent the cost of foundations, and a square meter profile cost, which may reflect the profile area of retaining wall, the study team defined retaining wall cost as simply $960 per square meter profile.

Viaduct – Similar to retaining walls, the cost of a length of viaduct includes a fixed component for foundations plus a variable component related to its height. The study team chose to define the cost of viaducts as:

- Cost of bridge superstructure $10,800 per meter
- Cost of piers and foundations $500 per square meter profile

The breakdown of these numbers is not critical since the cost is applied per lineal meter.

Tunnel - Costed as a linear function of its length. Tunnels were therefore defined as $31,440 per meter.

Culverts/Drainage - As previous work simply considered the cost of minor drainage and culverts to be in the order of 5% of the earthworks and pavement cost, this assumption was reiterated in this study. The system however does allow culverts to be defined on the basis of diameter or height, minimum cover requirements and unit cost.

Base - This represents the base and surfacing cost, which in this application relates to the track, ballast and fixed linear costs (over and above earthworks). This cost was input as $3,103 per meter. This rate is based the following assumptions:

- Ballasted Track Bed $781/m
- Fencing $80/m
- Signaling $665/m
- Communications $550/m
- Wayside Protection Systems $52.8/m
- Power Supply $340/m
- Power Distribution $634/m

4.5 LINEAR FEATURES/CONSTRAINTS

The study team defined linear features/constraints for roads, rivers, railways and pipelines including defining method of crossing and crossing clearance requirements.

Quantm allows an unlimited number of linear features to be included in the formulation of the problem. This data can be input either digitally or manually using a simple 'point and click' mouse routine.

For example, in the Pacheco Pass investigation, the SR-152 was defined as a constraint that must be crossed by a structure (overcrossing bridge, undercrossing or tunnel) with a minimum clearance of 6m above or 8m below the existing highway. The data for the SR-152 was derived from GIS.

4.6 SPECIAL TREATMENT ZONES/CONSTRAINTS

The study corridor contains zones that require special treatment for social, technical or environmental reasons. If the alignment is allowed to pass through such a zone it may be forced into a cutting or tunnel to reduce noise or visual impacts, or onto a viaduct with a minimum elevation when crossing a flood plain.

The study team defined special treatment zones/constraints for avoidance (no-go) areas, water zones (dams and lakes), extra cost areas (land clearances or land acquisition), earthwork limits (maximum cut/fill heights) and other constraints, such as avoiding State/National Parks areas through tunneling.

4.6.1 Environmental Constraints

All of the environmental constraints and their locations were derived from existing GIS data either gathered during the previous studies or currently being obtained. Examples of some of the key constraints defined to date include:

Floodplains: An ArcView GIS shapefile was created that shows the various drainage locations that are classified as areas within a 100-year floodplain. This file was converted to Quantm format by Quantm's technical team.

Threatened and Endangered Species: A shapefile was created that established polygonal areas for threatened and endangered species habitat and known travel corridors. This information is provided by the National Diversity Database (NDDB) that gives the locations of both habitats and spotting sites for both state and federal registered species. For example, the California Condor is a very protected endangered species in the state of California. Several sites within the Tehachapi Mountains have been established to provide sanctuary for Condors that have been relocated or released from captivity. The boundary for the condor areas were established and inserted into the Quantm system as an environmental constraint.

Parks and Recreation Areas: ArcView shapefiles were also created that showed all of the National and State Parks, as well as all established National and State Recreation areas. The site boundaries were also converted to Quantm format and used as environmental constraint areas.

Farmland: Due to the large population and overall value of the farming market in the northern central valley and Gilroy areas, significant farmland locations had to be shown for the Pacheco Pass study area. Areas with Unique Farmland, farmland of Statewide Importance, and agricultural lands considered Prime Farmlands in the GIS farmland database were found and their locations were input and considered as constraints.

5.0 ALIGNMENT ANALYSIS AND RESULTS

The alignment refinement and optimization study was completed following the general approach described in Section 3.4. For each corridor numerous tests were completed using the Quantm system. The Quantm process is iterative. Millions of potential alignments were generated from each test. The study team reviewed the results from each test and formulated subsequent Quantm test runs. The results presented in this chapter represent only a summary of the key alignment information and comparisons. The alignments shown herein are representative of the alignment modifications and potential associated infrastructure and cost savings that were identified with the Quantm system. The alignments will be reviewed for specific geometric parameters prior to being studied in the detailed analysis of the Program EIR/EIS.

The alignment costs are presented only as an indicator of potential savings and should not be misconstrued as absolute or all inclusive costs. The alignment costs shown are comprised of construction costs of alignment infrastructure and do not include right of way acquisition or many of the other costs necessary to implement an operational high-speed train line/system.

The results below were achieved in just three weeks; with a considerable amount of the first week being allocated to defining and refining constraints and features to model the assumptions that were the basis of the alignments previously developed using the conventional planning/engineering approach. This ensures that the results achieved by the study team with the Quantm system can be confidently compared with those alignments determined in the conventional manner.

In the section below, the results of the Quantm alignment refinement and optimization study are compared to the alignment options developed during the current alignment screening evaluation as well as alignment options that were developed in the previous Corridor Evaluation Study (1999). There is typically a wide difference in the infrastructure requirements (tunnel and structure length) of the alignment options developed in these two studies, due to the differing objectives of the two studies. It is important to note that the current screening evaluation focused on minimizing potential environmental impacts, while the previous corridor evaluation study focused on minimizing tunnel requirements and cost. Based upon the results of the Tunneling Conference, the Quantm study has attempted to minimize tunneling and capital costs, and therefore is more comparable to the earlier Corridor Evaluation Study results.

5.1 NORTHERN MOUNTAIN CROSSING – DIABLO MOUNTAINS

Two primary corridors have been considered in the screening evaluation to date to cross the northern mountain pass (Diablo Mountains): the Pacheco Pass through the State Route (SR-152) corridor to Gilroy and a northern alignment that connects more directly to the San Jose area.

5.1.1 Northern Crossing - Diablo Range Direct

A. Screening Alignment Option – Northern direct tunnel (Alignment 1~seed)

Of the two primary corridors being considered in the Diablo Mountain Crossing, the northern alignment is advantageous in terms of travel time; however, the terrain is more difficult and remote. Because of time and resource constraints, the previous northern alignment studies in the screening evaluation had assumed that the crossing needed to be completely in tunnel because of the difficult and remote terrain. As a result, the only alignment considered included a 31-mile long tunnel through the mountain crossing. A tunnel of this length, however, is costly and difficult to construct.

Figure 5-1 shows the alignment and summary information for the previously developed alignment (Alignment 1~seed) indicating an alignment construction cost of $4.22 billion. It should be noted that this cost is based on the per mile construction cost of a maximum single tunnel length of 6 miles. The alignment cost of this alignment including the appropriate tunnel cost for over 6 miles in length would be over $4.22 billion. The alignment crosses three active and potentially active faults in tunnel, including the Ortigalita Fault, the southern extension of the Greenville Fault trend, and the Calaveras Fault zone.

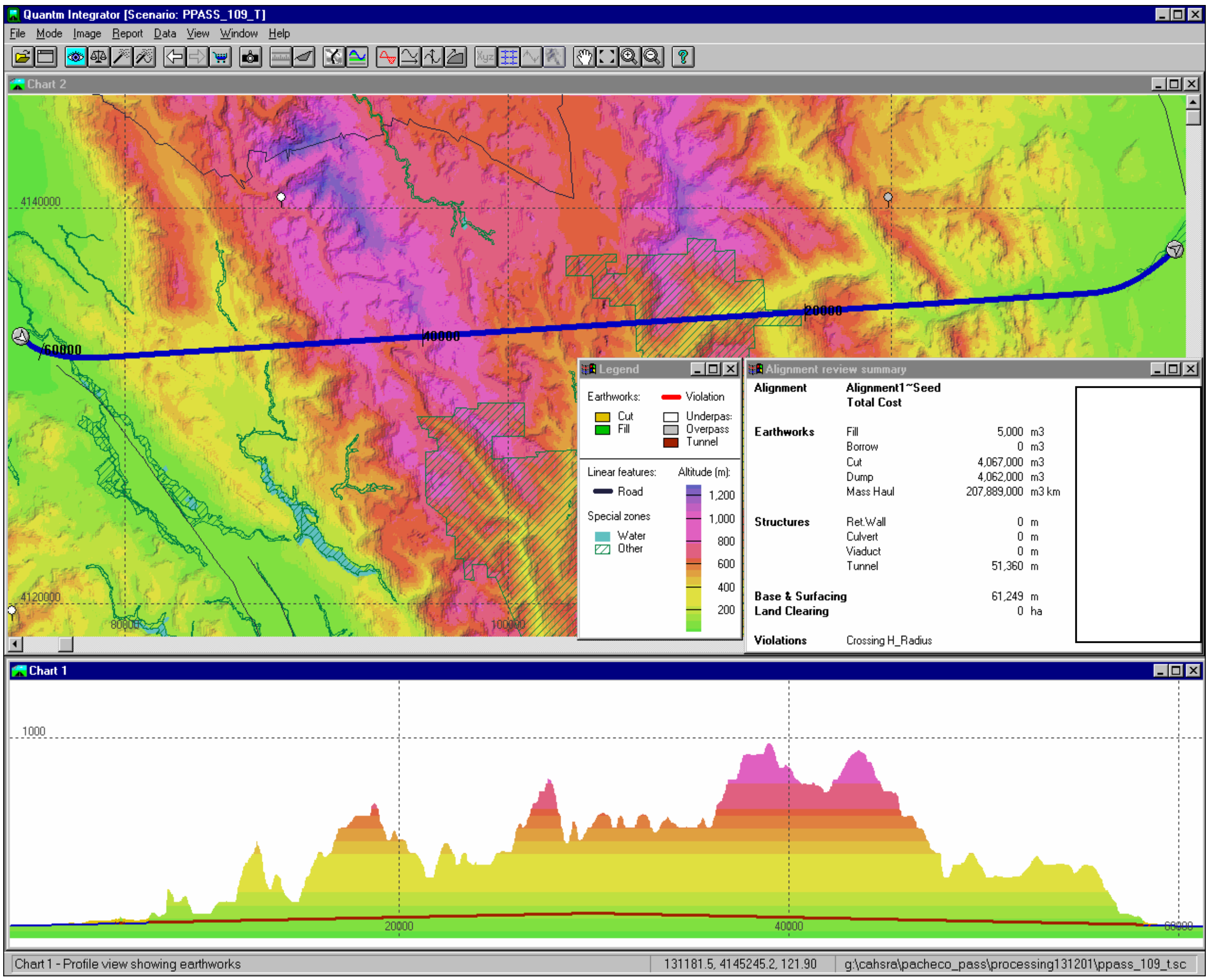

FIGURE 5-1: NORTHERN DIRECT TUNNEL – ORIGINAL ALIGNMENT (VERTICAL ALIGNMENT APPROX. ONLY)

B. Quantm Derived Alignments

Using the Quantm system the study team was able to identify alignments that met both the maximum grade of 3.5% and the maximum single tunnel length of 6 miles. They also substantially cut the forecast alignment construction cost.

Figure 5-2 shows a northern crossing alignment (PPASS_110_T1_4) with an alignment construction cost of $1.40 billion and a maximum single tunnel length of 4.9 miles. This alignment option crosses all three known faults at-grade.

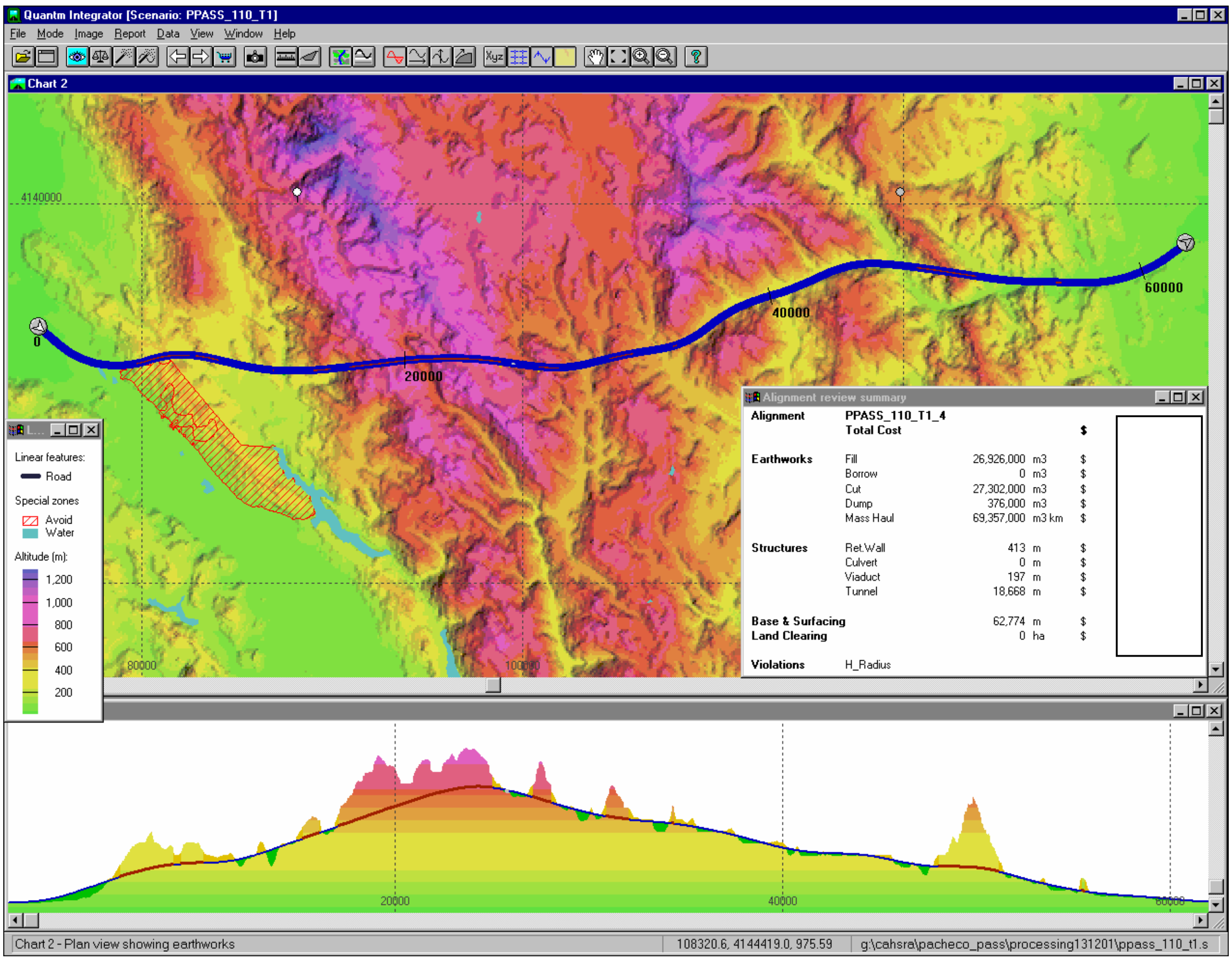

FIGURE 5-2: DIABLO RANGE DIRECT – QUANTM ALIGNMENT (3.5% MAX GRADE)

Figure 5-3 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. PPASS_114_T1_15 has an alignment construction cost of $1.36 billion and a maximum single tunnel length of 2.2 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 18.1% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 2.9%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

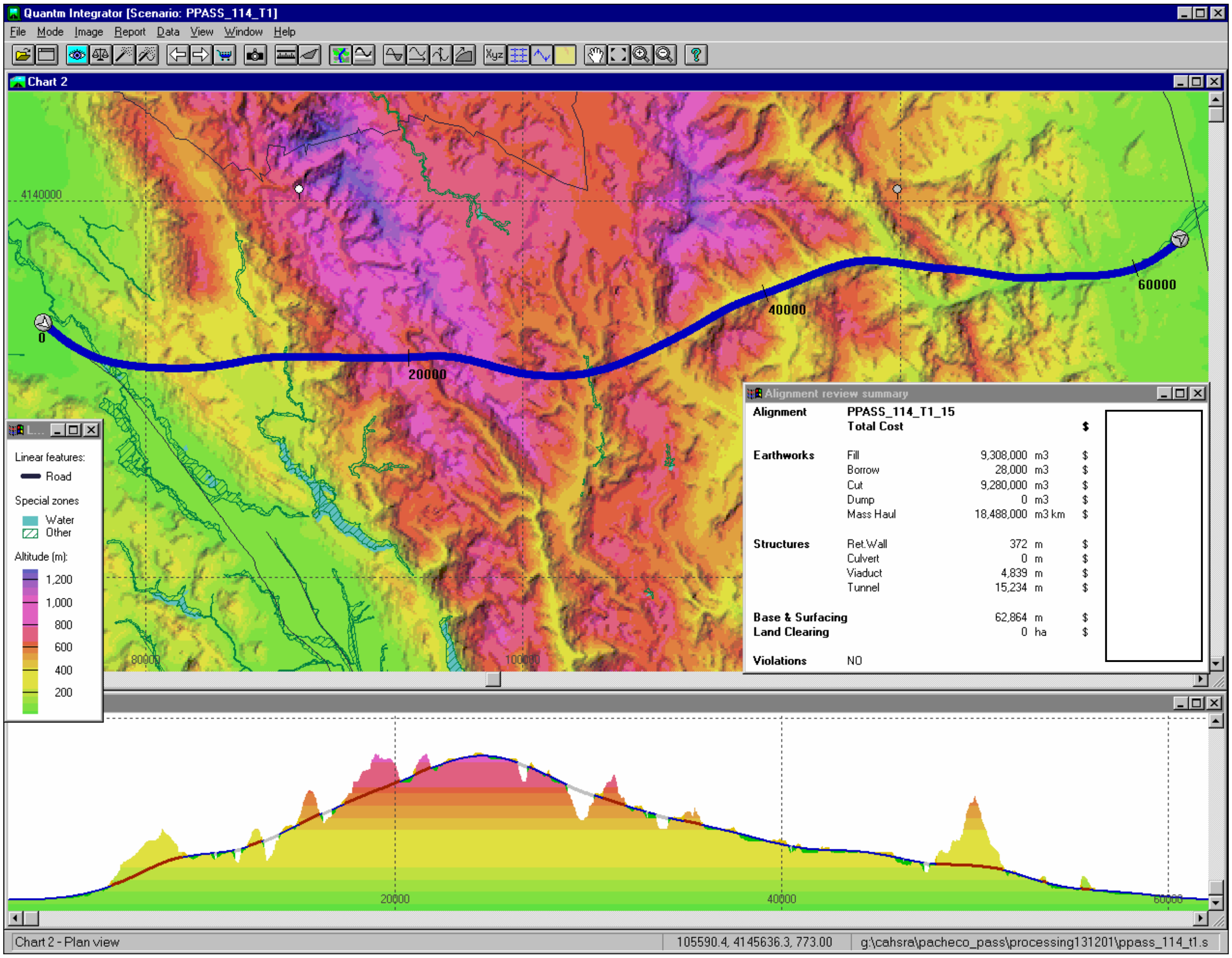

FIGURE 5-3: DIABLO RANGE DIRECT – QUANTM ALIGNMENT (5.0 % MAX GRADE AND 40M MAX CUT & FILL)

Henry W. Coe State Park is located in the Diablo Mountains between SR-152 and SR-130. To test the possibility of avoiding impact to the park area, alternative alignments were developed in Quantm that passed under the parkland in tunnel. Figure 5-4 shows a northern crossing alignment (PPASS_109_T_18) with tunnel under Henry W. Coe State Park. This resulted in an increase in tunneling required and the associated alignment construction cost (up to $1.76 billion) with a maximum tunnel length of 5.5 miles – still within the 6 miles desirable maximum.

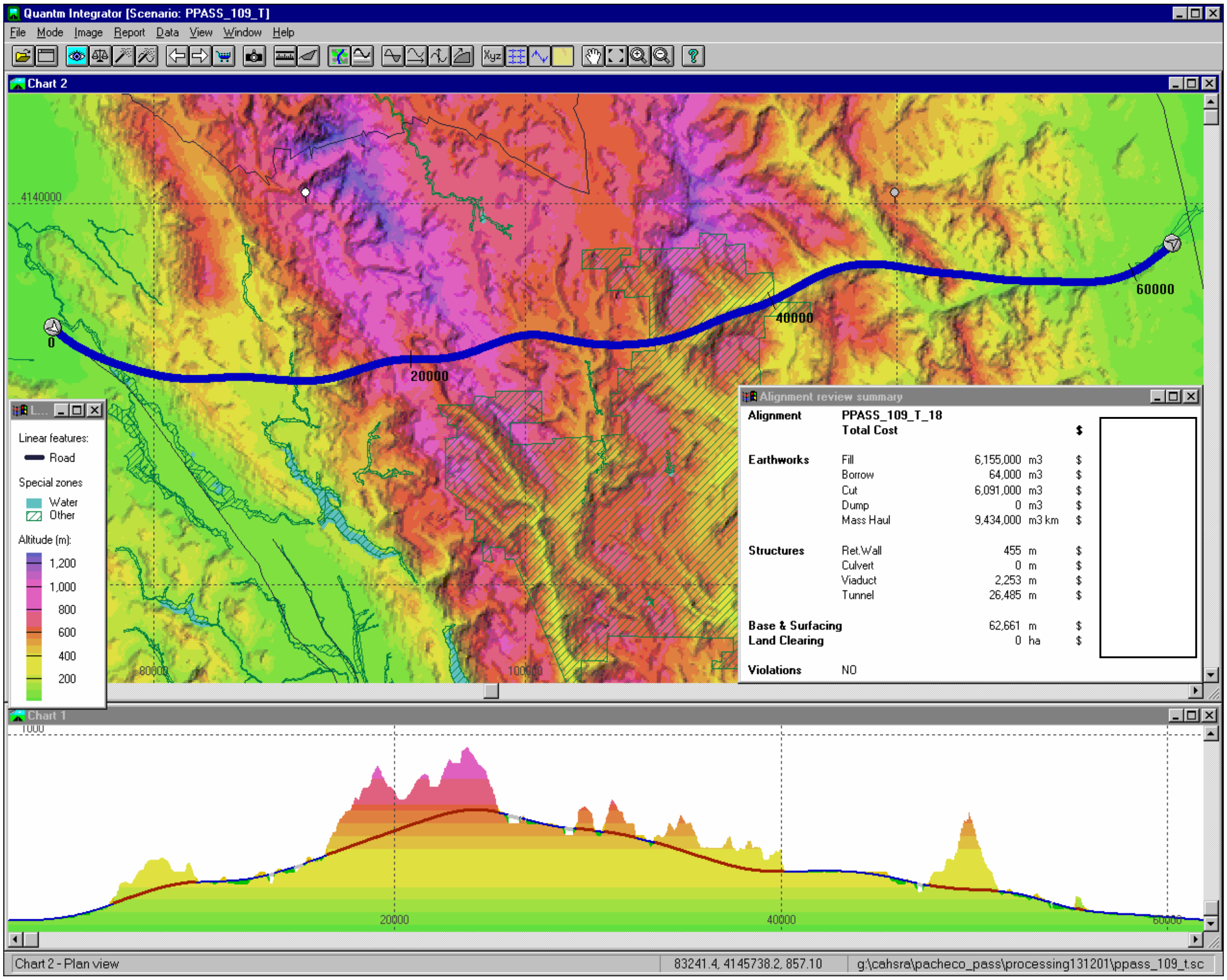

FIGURE 5-4: DIABLO RANGE DIRECT – QUANTM ALIGNMENT WITH CONSTRAINT FORCING THE HENRY W. COE STATE PARK TO BE CROSSED IN TUNNEL AT 3.5% MAX GRADE

Figure 5-5 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. PPASS_115_T1_8 has an alignment construction cost of $1.71 billion and a maximum single tunnel length of 4.2 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 9.7% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 2.8%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

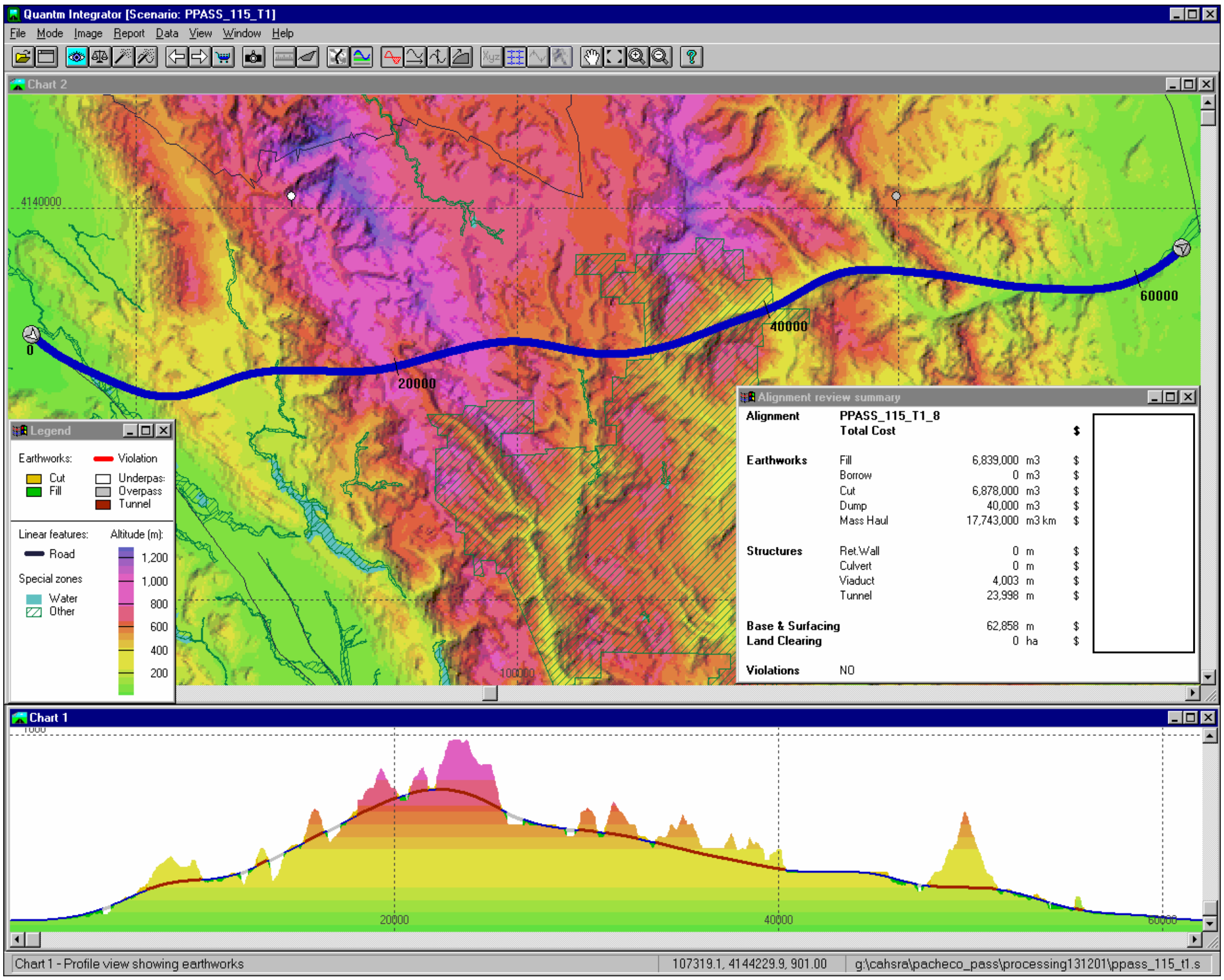

FIGURE 5-5: DIABLO RANGE DIRECT – QUANTM ALIGNMENT WITH CONSTRAINT FORCING THE HENRY W. COE STATE PARK TO BE CROSSED IN TUNNEL AT 5.0% MAX GRADE AND 40M MAX CUT & FILL

Another consideration in the proposed northern alignment is the need for construction access in this remote mountain area. Earthwork and particularly tunneling operations will require construction access (roads, staging areas) that is both costly and disruptive to the surface land. To avoid the cost and impact of lengthy access roads, the study team also considered the implications of an alternative alignment further north to be closer to SR-130, which could be used as an access road for tunneling and heavy construction machinery. In addition, an alignment further north would avoid the Henry W. Coe State Park altogether.

Several alternative alignments were identified in Quantm. Figure 5-6 shows a range of potential alignments that approach or even cross SR-130.

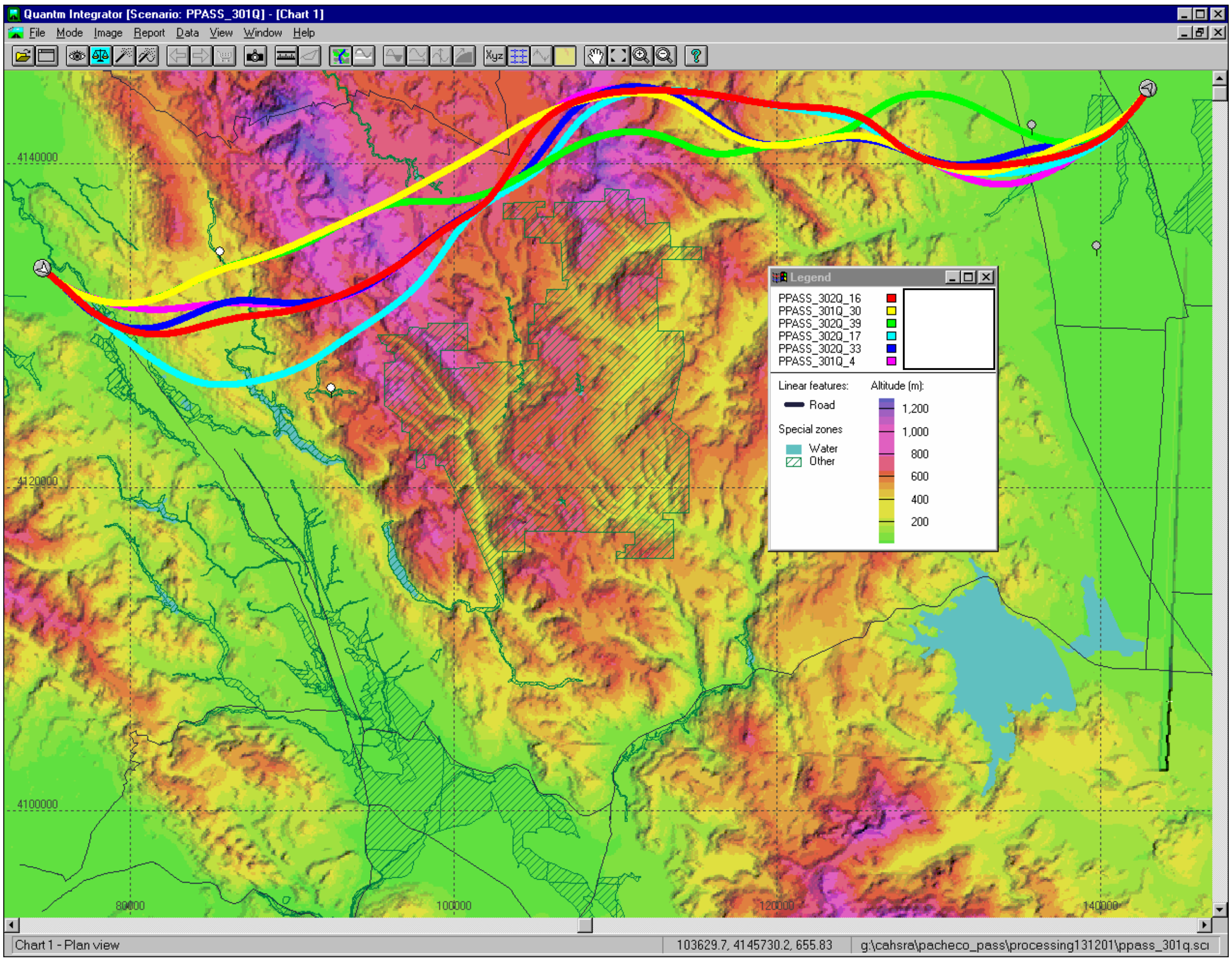

FIGURE 5-6: DIABLO RANGE DIRECT – QUANTM ALIGNMENTS CLOSE TO SR-130 (3.5% MAX GRADE)

Figure 5-7 shows one of the potential alignment options identified by Quantm that allows for construction access in close proximity to the tunneling locations. Tunneling is limited to a total of 16 miles and all tunnels within the desirable maximum single tunnel length of 6 miles.

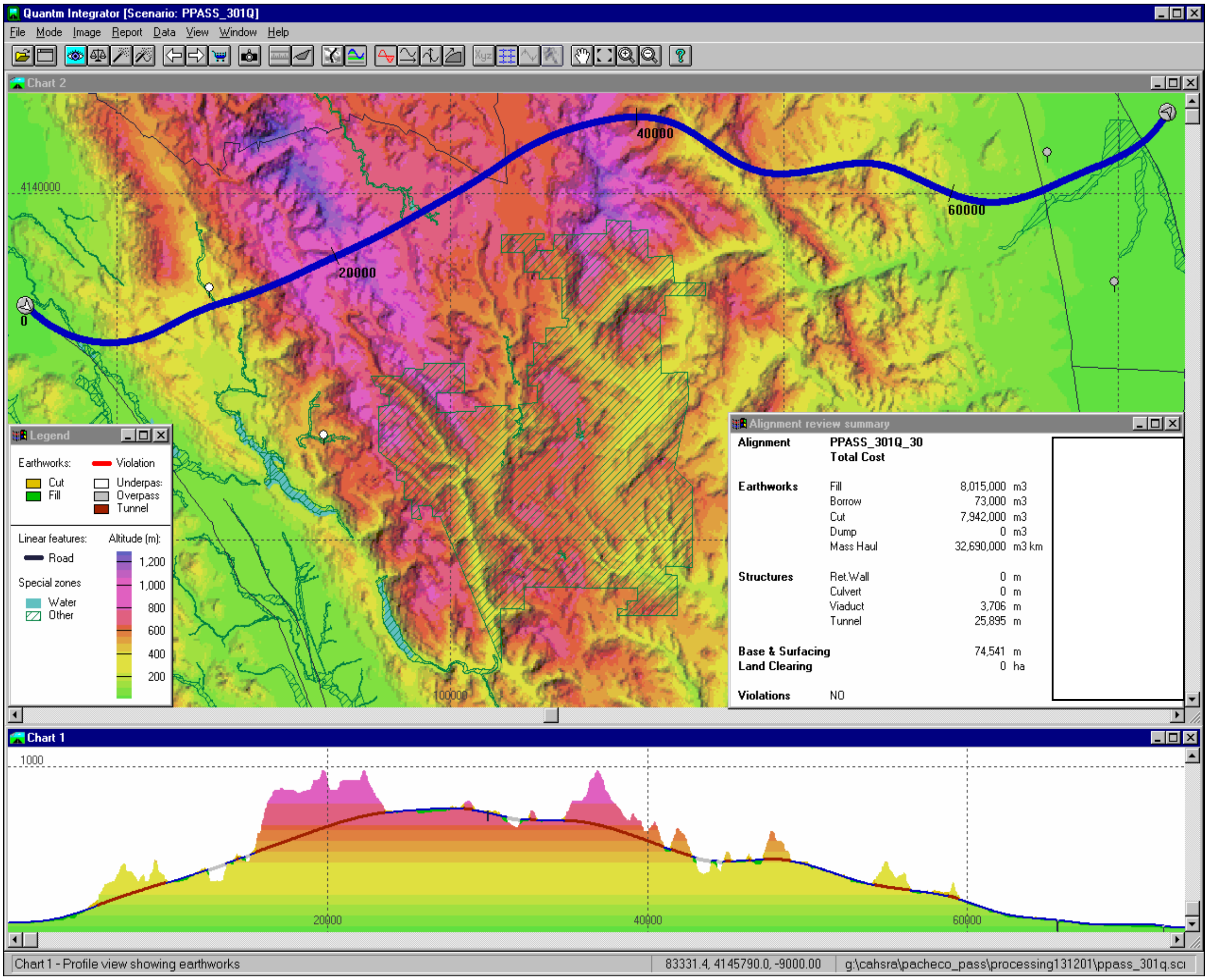

FIGURE 5-7: DIABLO RANGE DIRECT – QUANTM ALIGNMENT CLOSE TO SR-130 (3.5% MAX GRADE)

Figure 5-8 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. PPASS_307Q_32 has an alignment construction cost of $1.65 billion and a maximum single tunnel length of 2.2 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 31.1% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 12.2%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

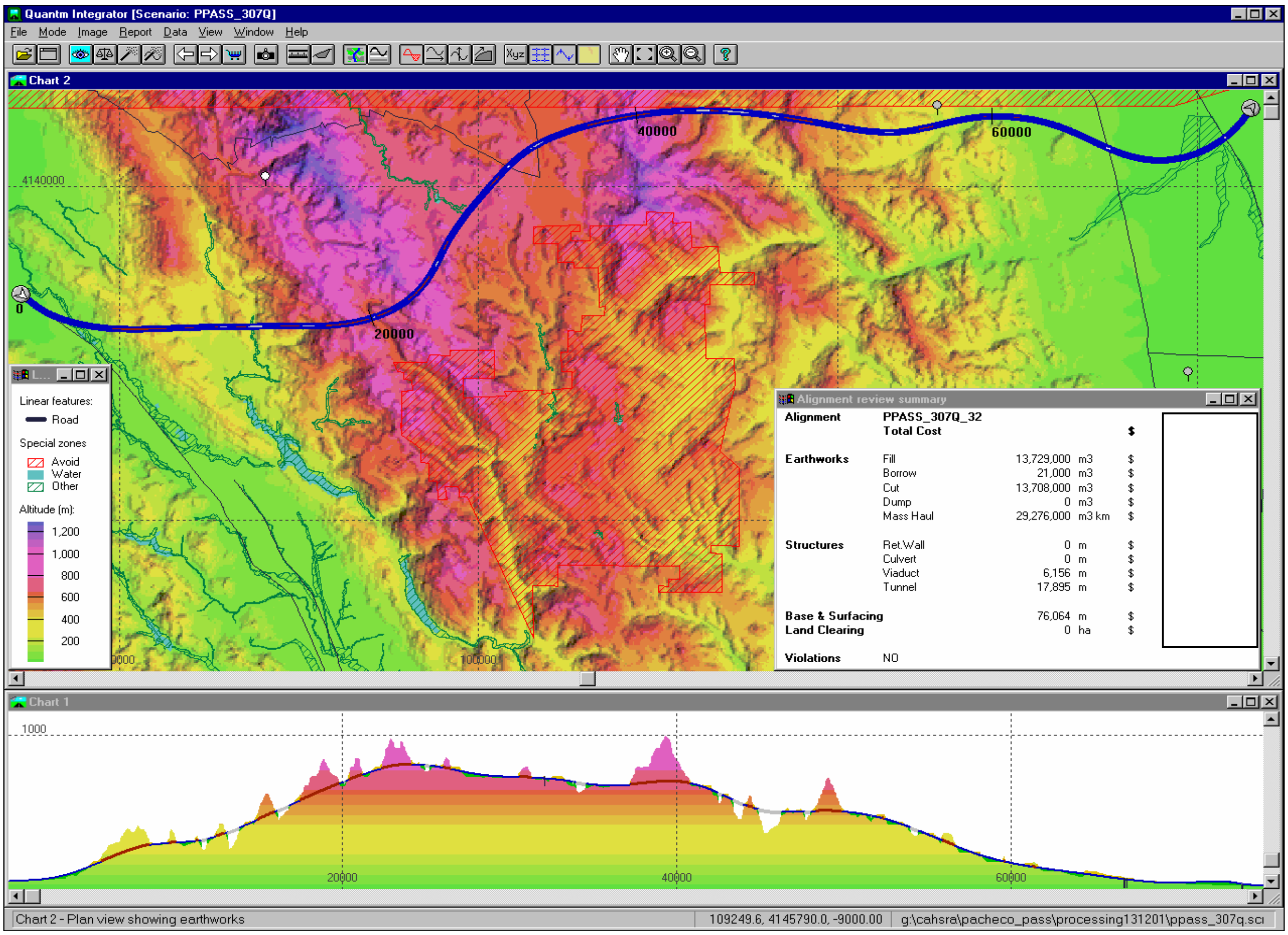

FIGURE 5-8: DIABLO RANGE DIRECT – QUANTM ALIGNMENT CLOSE TO SR-130 (5.0% MAX GRADE AND 40M MAX CUT & FILL)

Table 5-1 presents key infrastructure and cost comparison points between the screening alignment option previously identified and the new alignment options identified in this refinement study. The results indicate alignment options that minimize tunneling (requiring only 11.3 miles) and avoid direct impact to the Henry W. Coe State Park and are located in close proximity to SR-130 for construction access. The alignment options would significantly reduce the cost of this crossing and increase the construction feasibility by reducing the length of continuous tunnel to no more than 6 miles.

TABLE 5-1: NORTHERN ALIGNMENT COMPARISON SUMMARY

Alignment	Total Length	Total Tunnel Length	Maximum Tunnel Length	Alignment Construction Cost (billions)
Screening Alignment Option – Northern Direct Tunnel (Original Alignment-Alignment1~seed)	38.0 miles	31.9 miles	31.9 miles	$4.22
Alignment Option Minimizing Tunnel – Diablo Range Direct Max Grade 3.5% (Quantm – PASS_110_TI_4)	39.0 miles	11.6 miles	4.9 miles	$1.40
Alignment Option Minimizing Tunnel – Diablo Range Direct Max Grade 5.0% (Quantm – PASS_114_TI_15)	39.1 miles	9.5 miles	2.2 miles	$1.36
Alignment Option Crossing State Park in Tunnel – Diablo Range Direct Max Grade 3.5% (Quantm – PPASS_109_T_18)	38.9 miles	16.5 miles	5.5 miles	$1.76
Alignment Option Crossing State Park in Tunnel – Diablo Range Direct Max Grade 5.0% (Quantm – PPASS_115_TI_8)	39.1 miles	14.9 miles	4.2 miles	$1.71
Alignment Option Close to SR-130 and Avoiding State Park - Diablo Range Direct Max Grade 3.5% (Quantm – PPASS_301Q_30)	46.3 miles	16.1 miles	5 miles	$1.88
Alignment Option Close to SR-130 and Avoiding State Park - Diablo Range Direct Max Grade 5.0% (Quantm – PPASS_307Q_32)	47.3 miles	11.1 miles	2.2 miles	$1.65

5.1.2 State Route-152 Alignment

Based on the previous screening evaluation, the SR-152 Alignment generally follows the Pacheco Pass along the SR-152 corridor between Los Banos and Gilroy. From the pass area through Gilroy to San Jose there are complex urban and environmental constraints. Only the mountain crossing portion of this route was considered in this analysis. As with the northern alignment it also has potential impact to a major park and recreation facility at the San Louis Reservoir.

The alignment previously developed for this route was created without a digital vertical alignment (profile). Therefore, there is no profile benchmark for this alignment to be analyzed in the Quantm system; however, key comparison points are presented in the summary table (Table 5-2).

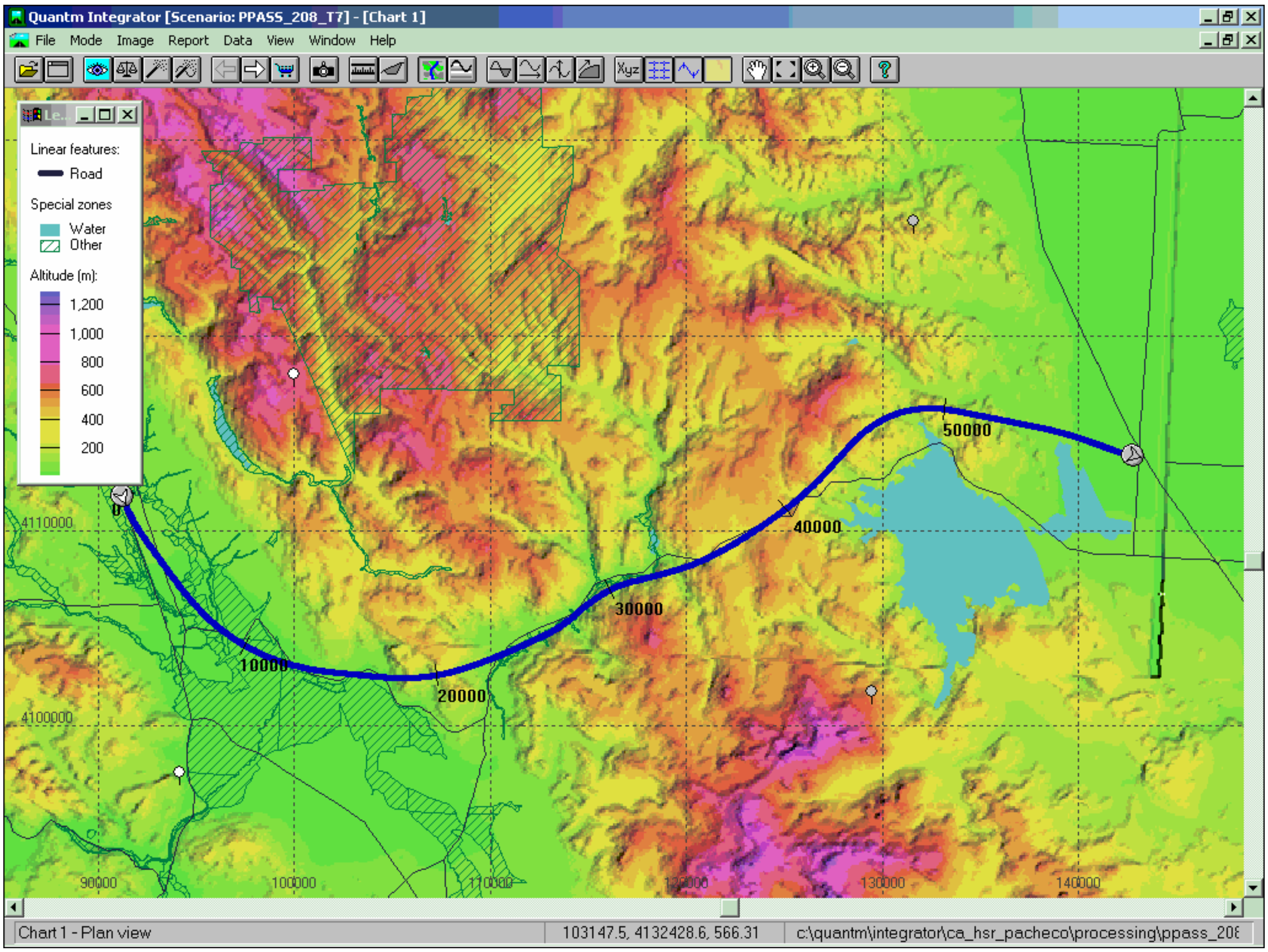

FIGURE 5-9: PACHECO PASS – SR-152 SEED ALIGNMENT (2D ONLY)

The study team used the alignment previously developed for the screening evaluation as a seed for the Quantm system to investigate alternative alignments in the vicinity. The Quantm system identified several alignment options in this corridor that minimized tunneling and the associated infrastructure costs. Figure 5-10 presents an alignment option that required significantly less tunneling than was estimated in the screening report (up to 13 miles less). This particular alignment option is somewhat more aggressive in terms of height of bridges than the previous studies, but it does show the potential for significant reductions in the amount of tunneling required. This particular option (PPASS_208_T7_17) has an alignment construction cost of $847 million.

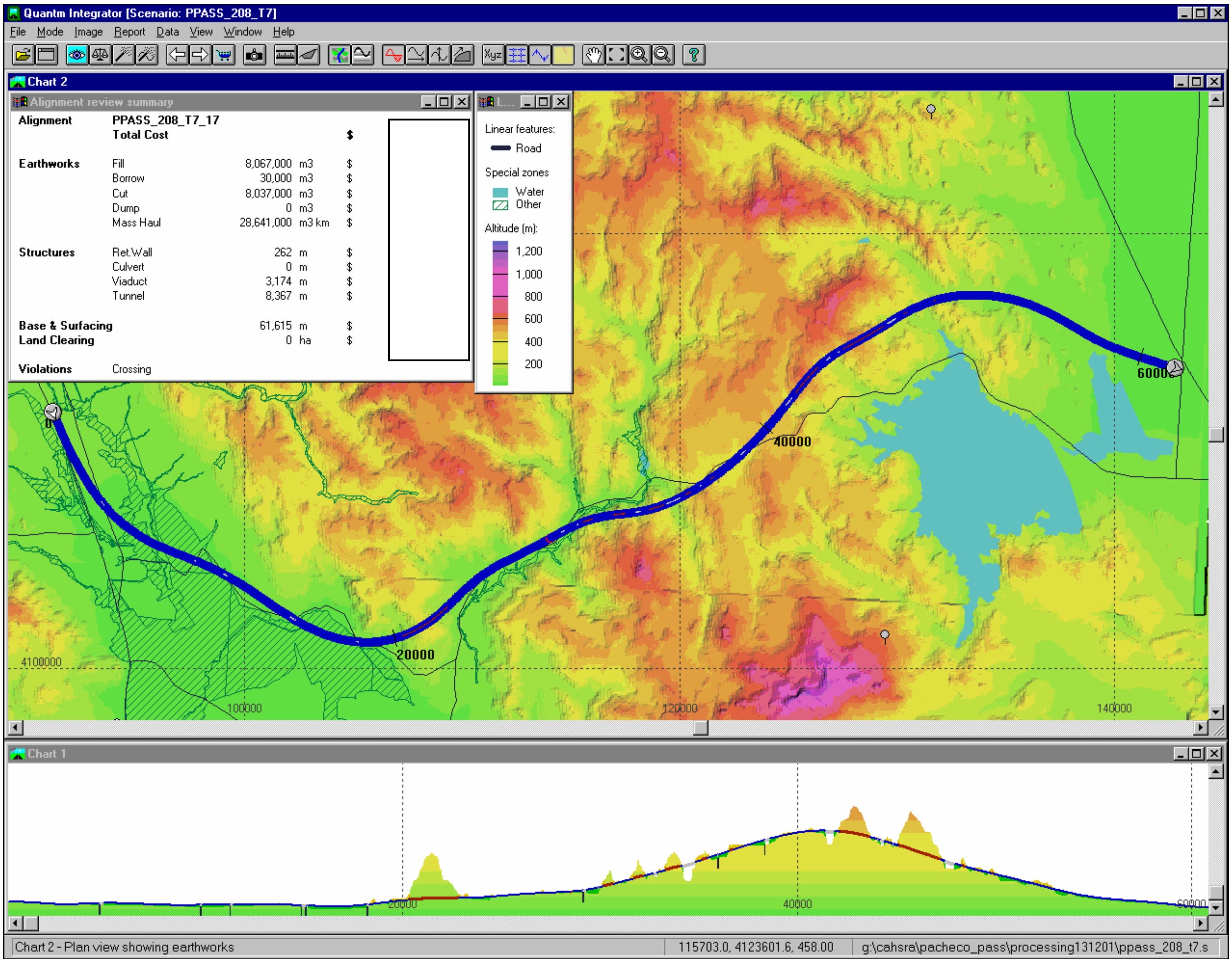

FIGURE 5-10: PACHECO PASS – QUANTM SR-152 ALIGNMENT (MAX. 3.5% GRADE)

Figure 5-11 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. PPASS_210_T7_19 has an alignment construction cost of $780 million and a maximum single tunnel length of 1.3 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 11.5% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 8.2%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

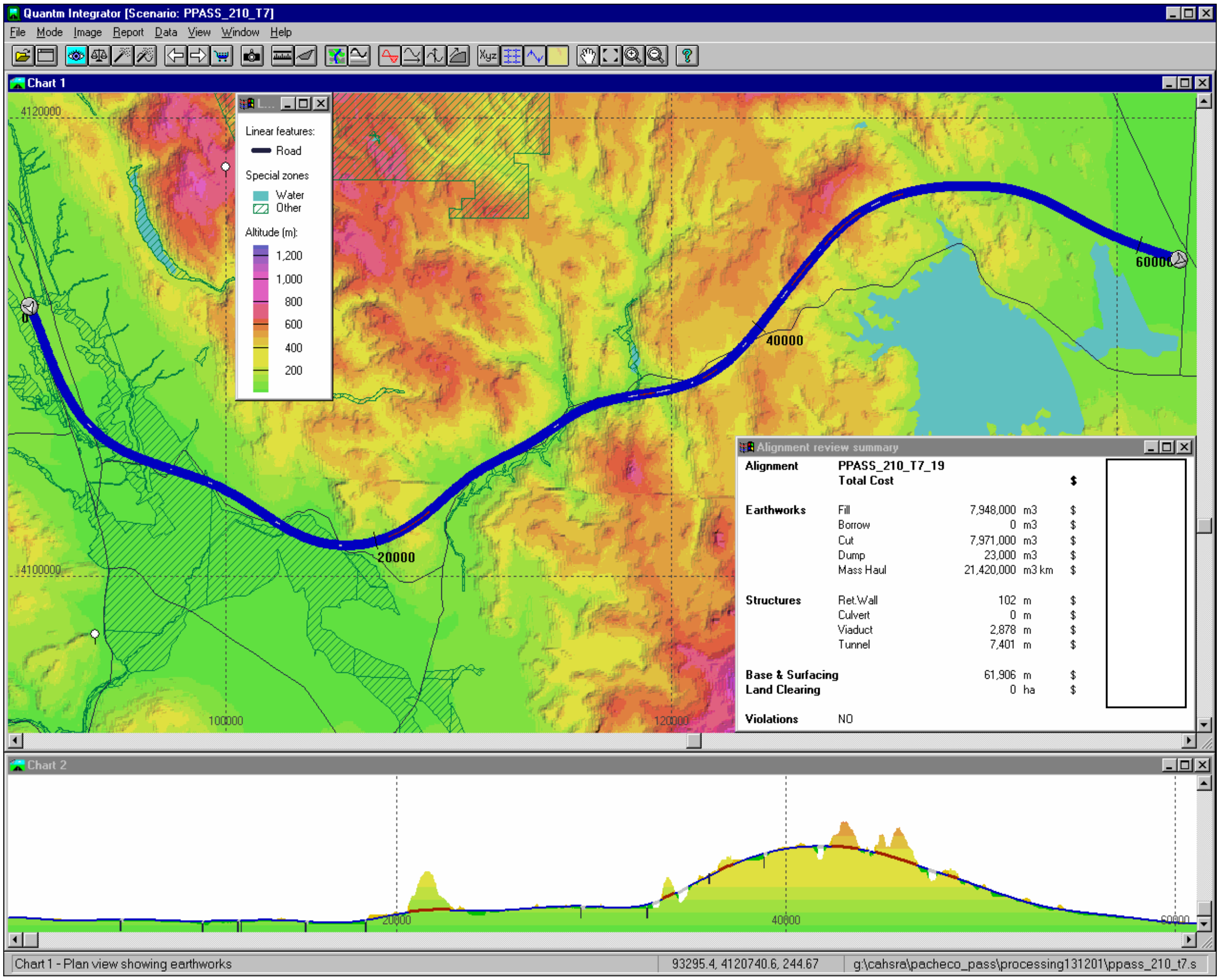

FIGURE 5-11: PACHECO PASS – QUANTM SR-152 ALIGNMENT (MAX. 5.0 % GRADE 40M MAX CUT & FILL)

TABLE 5-2: PACHECO PASS (SR-152) CORRIDOR COMPARISON SUMMARY

Alignment	Total Length	Total Tunnel Length	Maximum Tunnel Length	Alignment Construction Cost (billions)
SR-152/Pacheco Pass (Screening Alignment~seed)	39 miles	18 miles	15 miles	N/A
SR-152/Pacheco Pass (Previous Corridor Evaluation Alignment Option)	39 miles	12 miles	4.5 miles	N/A
Alignment Option Minimizing Tunnel Max Grade 3.5% (Quantm - PPASS_208_T7_17)	38.3 miles	5.2 miles	1.5 miles	$0.85
Alignment Option Minimizing Tunnel Max Grade 5.0% (Quantm - PPASS_210_T7_19)	38.5 miles	4.6 miles	1.3 miles	$0.78

5.1.3 Summary of Quantm Application on Pacheco Pass

The study of the northern mountain crossing using the Quantm system was completed in just three days, including terrain data input and conversion, constraints information transfer and alignment reviews. In addition, the ease of use and speed of the system was demonstrated with the definition of the Henry W. Coe State Park as a zone where the rail could only cross in a tunnel. The constraint was defined in minutes and new alignments that met this constraint were available for review in less than two hours. This has considerable implications for the environmental analysis and community consultation phases of the California High-Speed Rail project where the project planners will be expected to respond to new constraints and demonstrate comprehensive consideration of the issues raised. Impact mitigation and avoidance alternatives will be able to be developed and analyzed in a relatively short period of time.

The most important contribution to the northern mountain crossing at this stage of the project is the confidence gained that the optimal alignment options, in terms of minimized infrastructure requirements and cost is being studied. The significant reductions in tunneling and cost support this conclusion. A key example of this is the identification of an alignment option that meets the constraints, demonstrates that a crossing to the north of SR-152 is physically viable and has shown potential for significantly reduced tunneling and costs as well as impact.

5.2 SOUTHERN MOUNTAIN CROSSING - TEHACHAPI MOUNTAINS

Three primary corridor alignments are being considered through the Tehachapi Mountains: I-5 – Grapevine, SR-58, and the Aqueduct/SR-138. Numerous specific alignment options have been considered in each of these three general corridors. In addition, each of the alignments has been evaluated for a variety of profile grade options ranging from 1.5% to 5%. Currently, two different grade options are under consideration, a 2.5% gradient to optimize speed, power use and maintenance costs and a 3.5% gradient to minimize infrastructure costs (tunneling).

This alignment refinement/optimization study focused on the three general corridors with sensitivity tests for 2.5 – 3.5% maximum grades and other various environmental constraints. The specific screening evaluation alignment options used as comparison points are defined in Table 5-3 below.

TABLE 5-3: PREVIOUSLY DEVELOPED ALIGNMENT OPTIONS (SEEDS FOR QUANTM ANALYSIS)

Corridor Options	InRoads Horizontal	InRoads Vertical	Option Name	Description
I-5	Gv1/gv2/a	Gv1/2/a/	I5AltA (*)	I5 Alternative A (Max. 2.5%)
	Gv1/gv2/b	Gv1/2/b	I5AltB	I5 Alternative B (Max. 2.5%)
		Gv1/2/b/ult	I5AltBUlt	I5 Alternative B (Max. 3.5%)
I5 Comanche Point	Gv3	No vertical		Comanche Pass
SR58/Soledad	Sol/sr58	Sol/sr58	SolSR58 (*)	Av1/sol/av2/av3/av4 (Max. 2.8%)
		Sol/sr58/ult	SolSR58Ult	(Max. 3.5%)
		Sol/sr58/ult2	SolSR58Ult2	(Max. 3.5%)
		Sol/sr58/ult3	SolSR58Ult3	(Max. 3.5%)
SR58/SR-14	SR14	SR14	SR14SR58	(Max. 2.62%)
SR138	aqua	aqua	SR138	SR-138/aqua (Max. 2.62%)
Existing Aqueduct	avem	No vertical		Aqueduct ALG – No investigation
South of Project	Sfv1/3	Sfv1/3		In Ex ROW
South of Project	Sfv2/3	Sfv2/3		R=5000m Route 4-10-01

5.2.1 I-5/Grapevine

A. Screening Alignment Option (3.5% Maximum Grade)

The screening alignment option (I5AltBUlt~Seed) for this route is shown in Figure 5-12 with a construction cost of $4.48 billion. This alignment was the result of studies undertaken during the current screening evaluation, based on previous studies on this corridor. This option has a maximum single tunnel length of 14.3 miles.

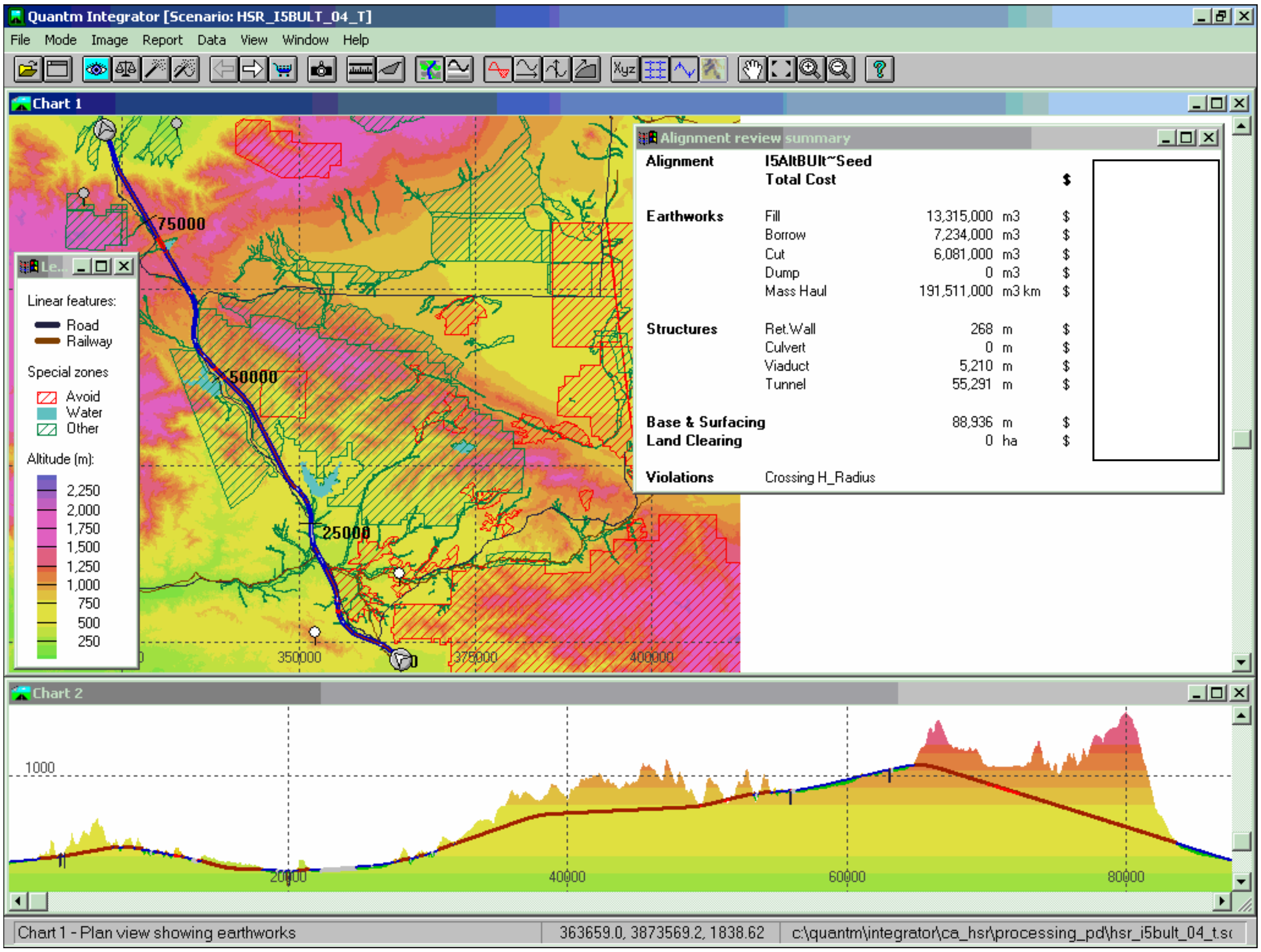

FIGURE 5-12: I-5 SCREENING ALIGNMENT OPTION (MAX. 3.5% GRADE)

B. Quantm Derived Alignments

The study team used the Quantm system to investigate alternatives in the vicinity of the Original alignment as well as tests to identify any other alignments outside this corridor that have similar or reduced costs and/or impacts.

The Quantm system identified several alignment and profile options that reduced the extent of tunneling. It is important to mention that the Quantm system aggressively minimizes tunneling. In some locations it may be more advantageous to have one longer tunnel than two or three very short tunnels, due to access and other environmental issues. These issues will have to be further considered during the more detailed phase of the Program EIR/EIS analysis. However, the Quantm identified alignment options indicate the potential to significantly reduce the infrastructure cost by reducing the tunneling required in this general corridor without compromising the basic geometric criteria of the high-speed train system.

Figure 5-13 shows an alignment option (HSR_I5bult_04_T_1) with an alignment cost of $2.93 billion and a maximum tunnel length of 10.6 miles.

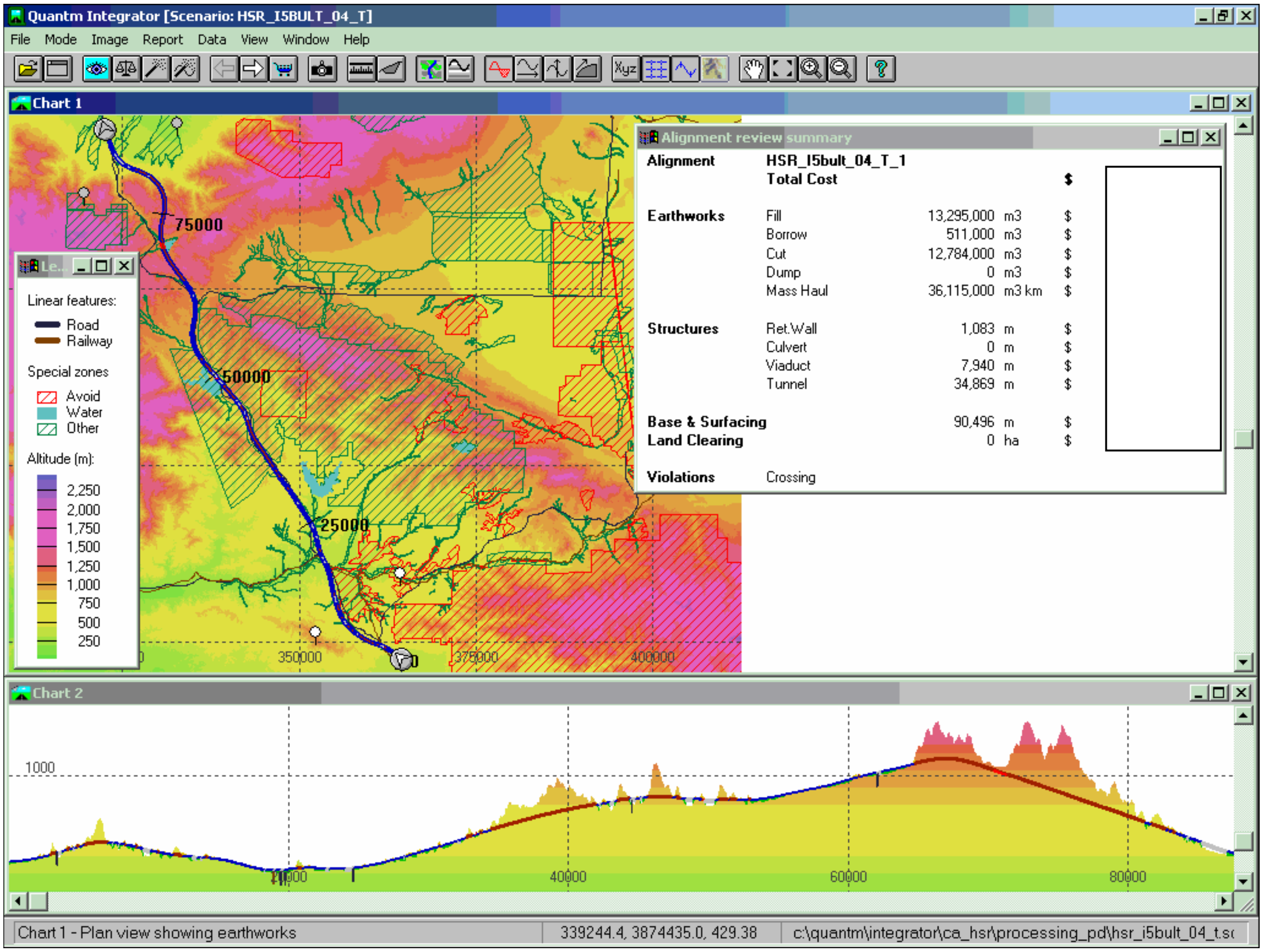

FIGURE 5-13: I-5 QUANTM ALIGNMENT (MAX. 3.5% GRADE)

Figure 5-14 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. I5_100_T_3 has an alignment construction cost of $1.99 billion and a maximum single tunnel length of 4.3 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 38.9% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 32.1%. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

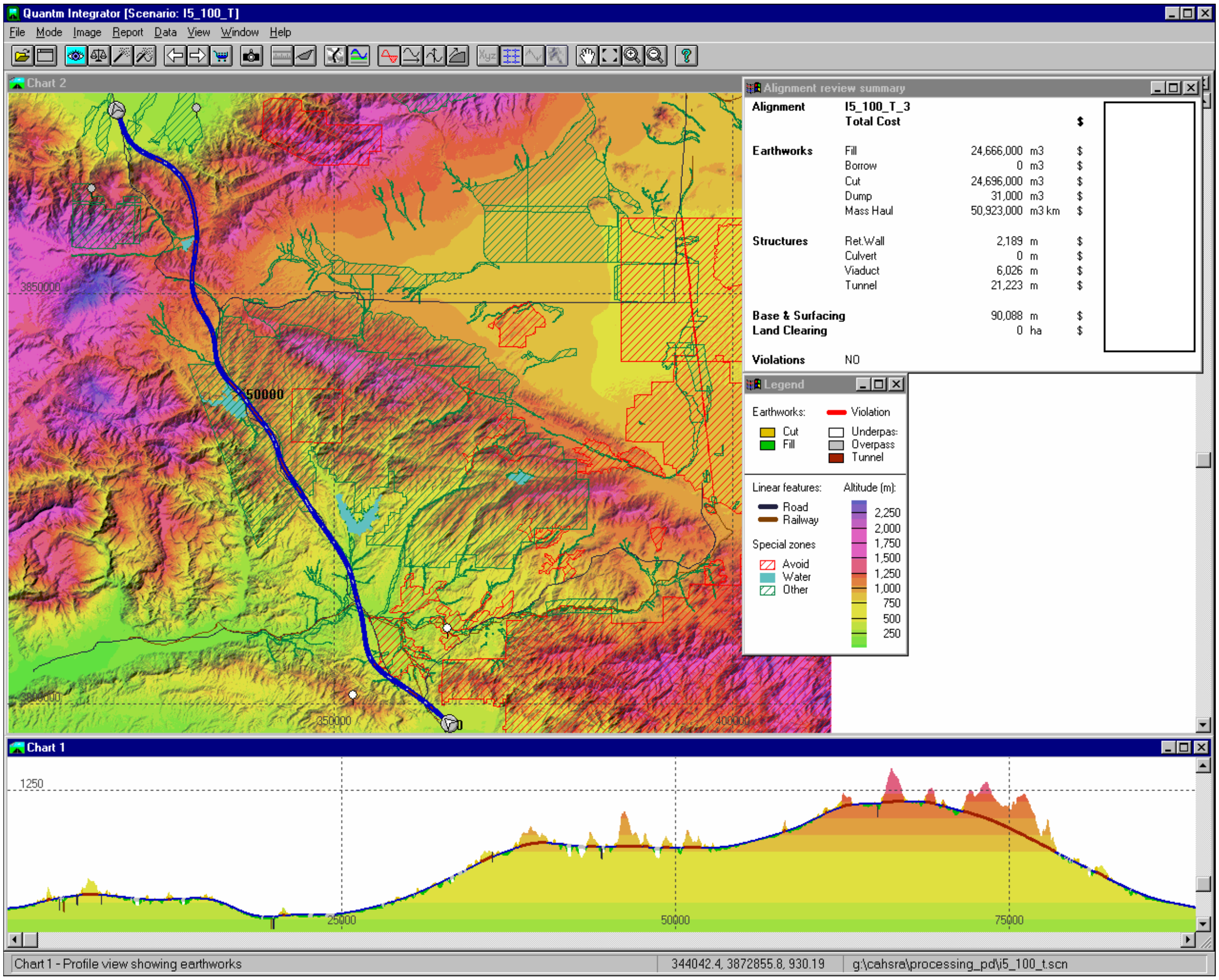

FIGURE 5-14: I-5 QUANTM ALIGNMENT (MAX. 5.0% GRADE 40M MAX CUT & FILL)

Figure 5-15 shows an alignment option (HSR_I5bult_04_T_5) in the same corridor with a construction cost of $3.04 billion and a maximum single tunnel length of 9.3 miles.

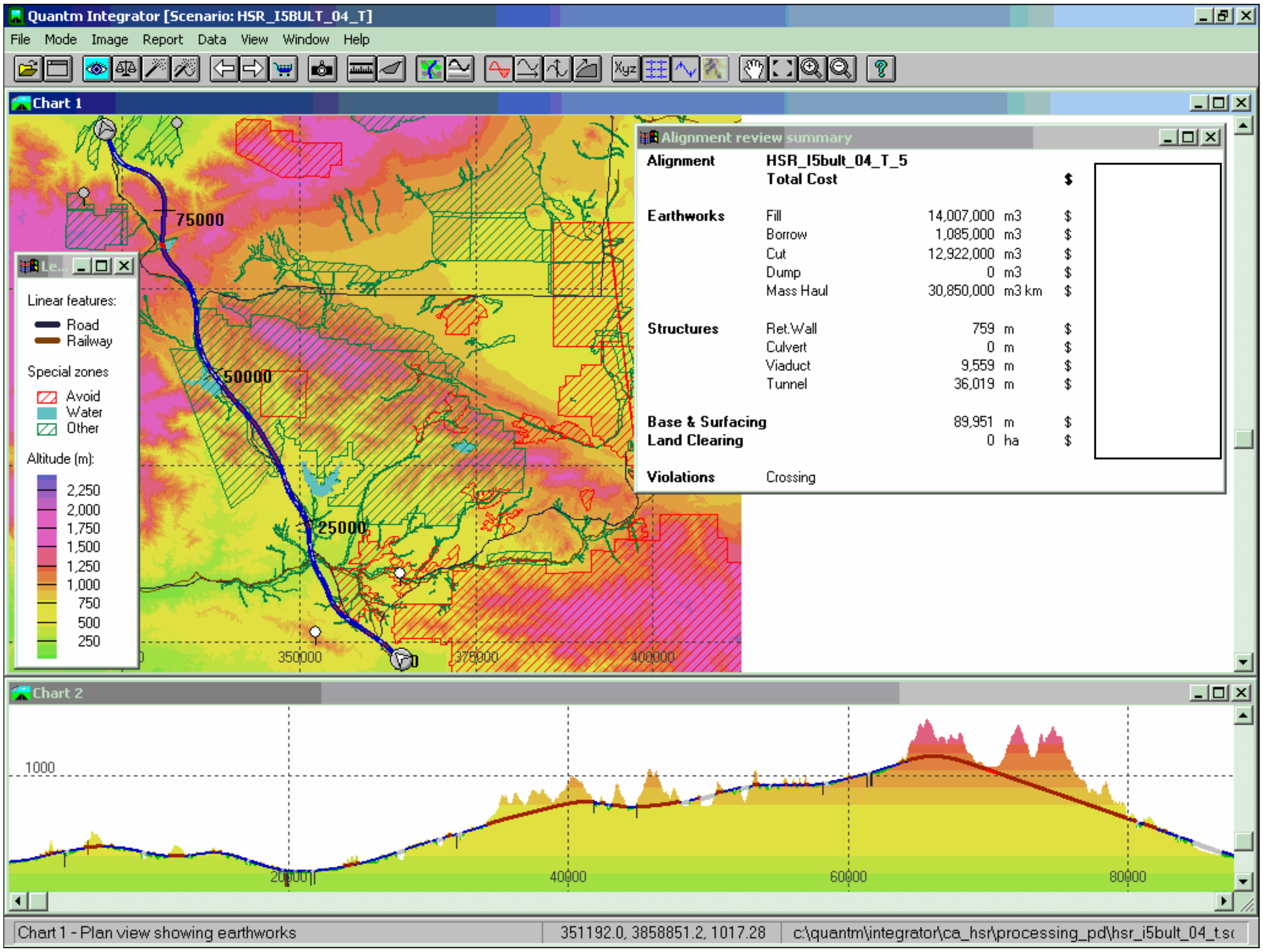

FIGURE 5-15: I-5 QUANTM ALIGNMENT (MAX. 3.5% GRADE)

C. Screening Alignment option (2.5% maximum grade) - Sensitivity Analysis

The I-5 corridor was also investigated in Quantm on the basis of a 2.5% maximum grade. Figure 5-16 shows the Screening Alignment Option with a construction cost of $5.36 billion with a length of more than 19.2 miles of tunneling. The lower maximum grade and associated tunneling was proposed on this option to avoid environmental constraints, maximize train performance, and minimize operational and maintenance costs.

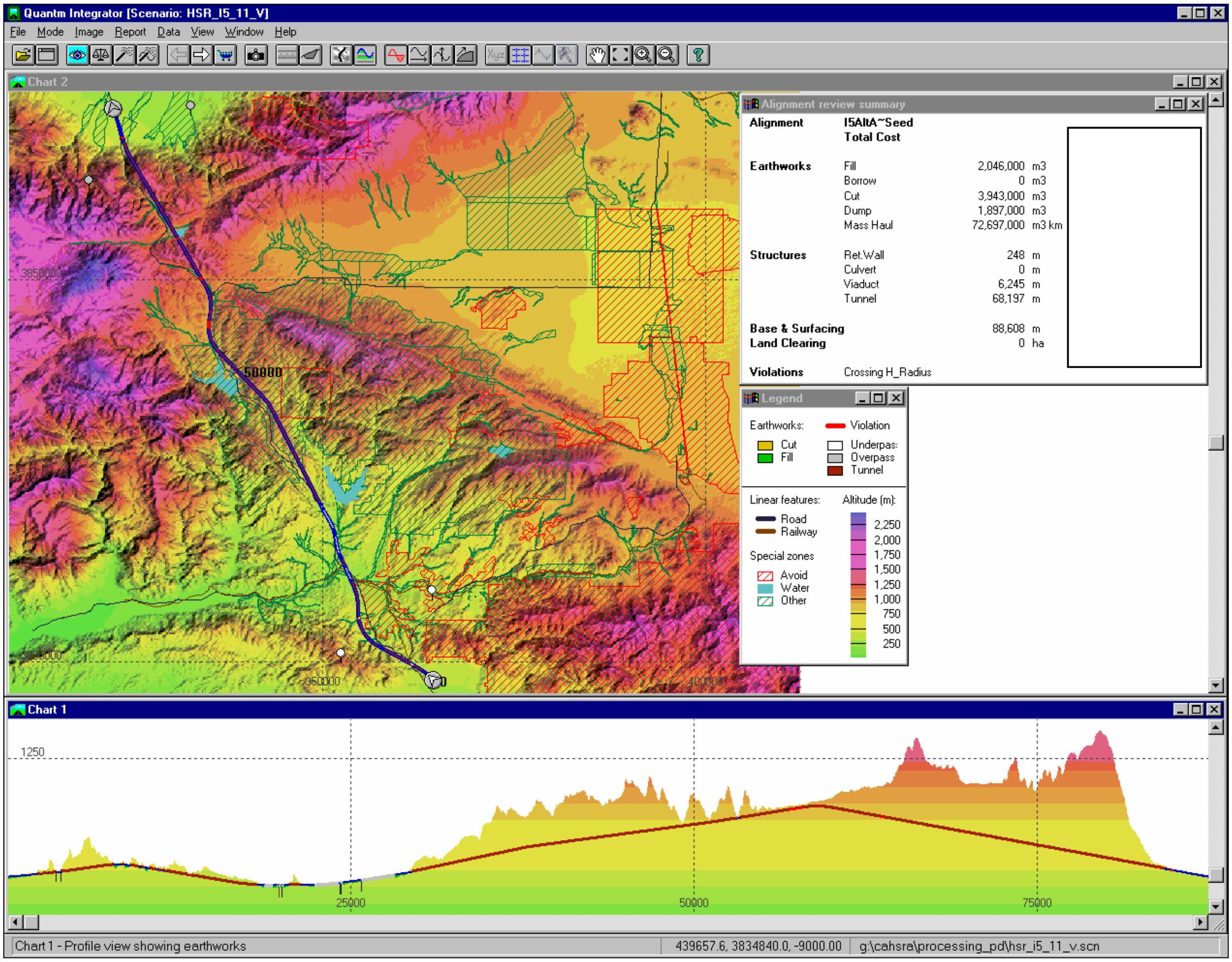

FIGURE 5-16: I-5 SCREENING ALIGNMENT OPTION (MAX. 2.5% GRADE)

D. Quantm Derived Alignments

For this 2.5% maximum grade option, the alignment refinement/optimization was focused on identifying alignment options with reduced tunnel length and associated cost. Quantm identified alignment options that reduced single tunnel length to as low as 14.7 miles. While this still exceeded the maximum desirable tunnel length, it did identify that significant reductions in tunneling length are possible, even with a maximum 2.5% grade.

Figure 5-17 shows an alignment option (HSR_15_11_V_12) with a maximum single tunnel length of 14.7 miles and a construction cost of $4.55 billion.

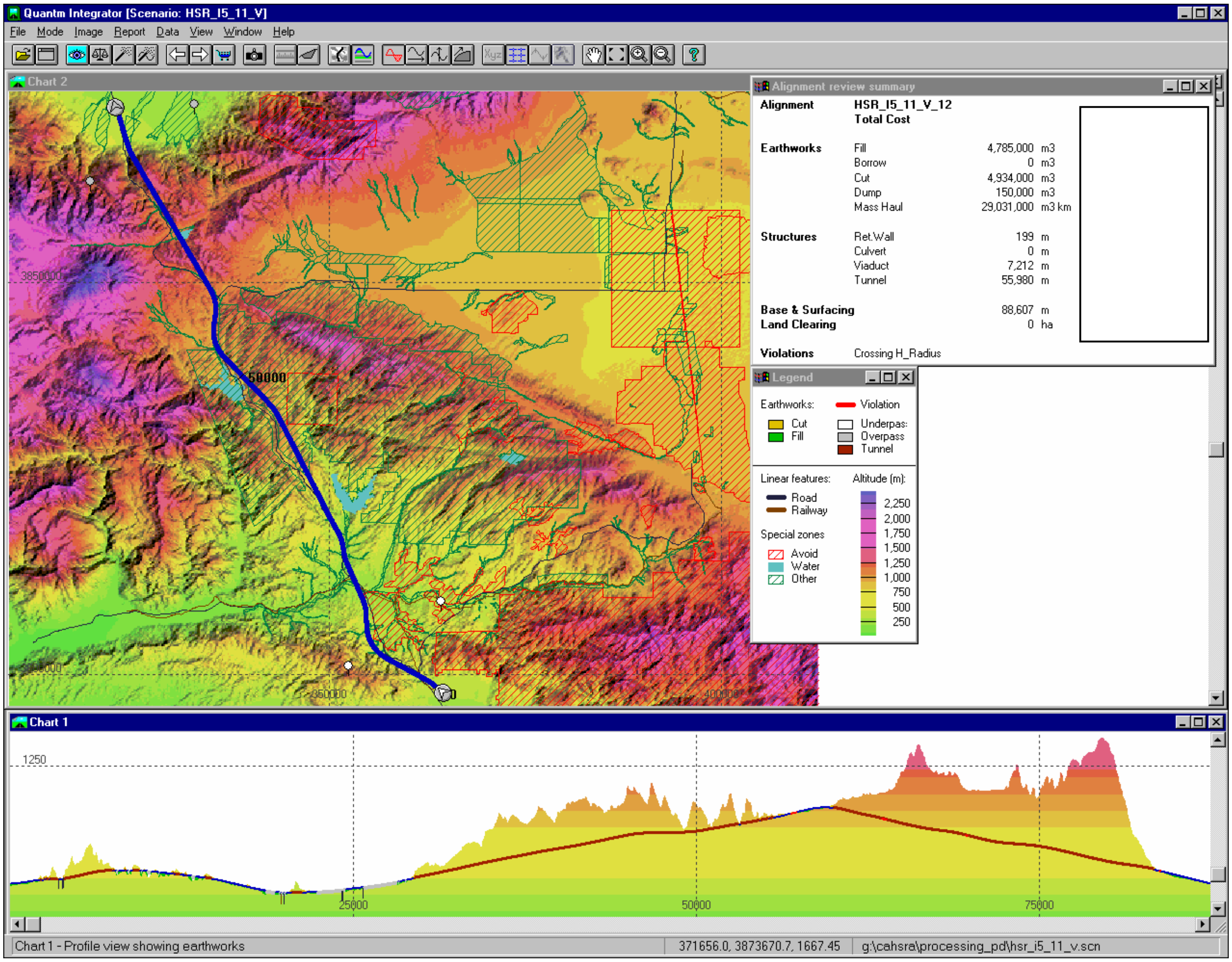

FIGURE 5-17: I-5 QUANTM ALIGNMENT AT MAX. 2.5% GRADE

E. Considering Fault Lines

The screening evaluation alignment options and the Quantm alignments (identified above) assumed a crossing of both the San Andreas and Garlock Fault zones (see Figure 5-18). In the 3.5% maximum grade alternatives the San Andreas Fault zone would be crossed primarily at grade with a tunnel portal at the northern edge of the zone and the Garlock Fault zone would be crossed at depth in a special wide tunnel section. In the 2.5% maximum grade options both fault zones would be crossed at depth in a special wide tunnel section. A considerable amount of extremely difficult geology lies between the two fault zones that would require very challenging tunneling techniques for either grade option. Because of the special construction required for an underground fault crossing and the difficult geology involved, each major underground fault crossing represents significant additional cost and potential construction delay implications.

Based on the extensive geologic constraints in this triangular area comprised of the fault zones and the earth between them, the study team used the Quantm system to investigate options that minimized the crossings or achieved a crossing at-grade (not requiring a tunnel). Several Quantm tests were performed to identify possible solutions/mitigations to the fault crossing issue. The first tests were intended to identify alignment options to the west of the junction of the San Andreas and Garlock Fault zones to reduce the fault crossings to one and to limit the amount of difficult geology to be traversed between and around the fault zones. There are several large ancient landslide areas to the west of I-5 in the area of the alignment options to be investigated. These areas were identified in the Quantm system as areas to be avoided. An alignment option was identified that crossed the San Andreas Fault zone beyond the junction of the Garlock Fault. The alignment option also avoided the major landslide areas. While this alignment option crosses only one fault zone, it must be crossed in tunnel at depth with a maximum grade of 3.5%.

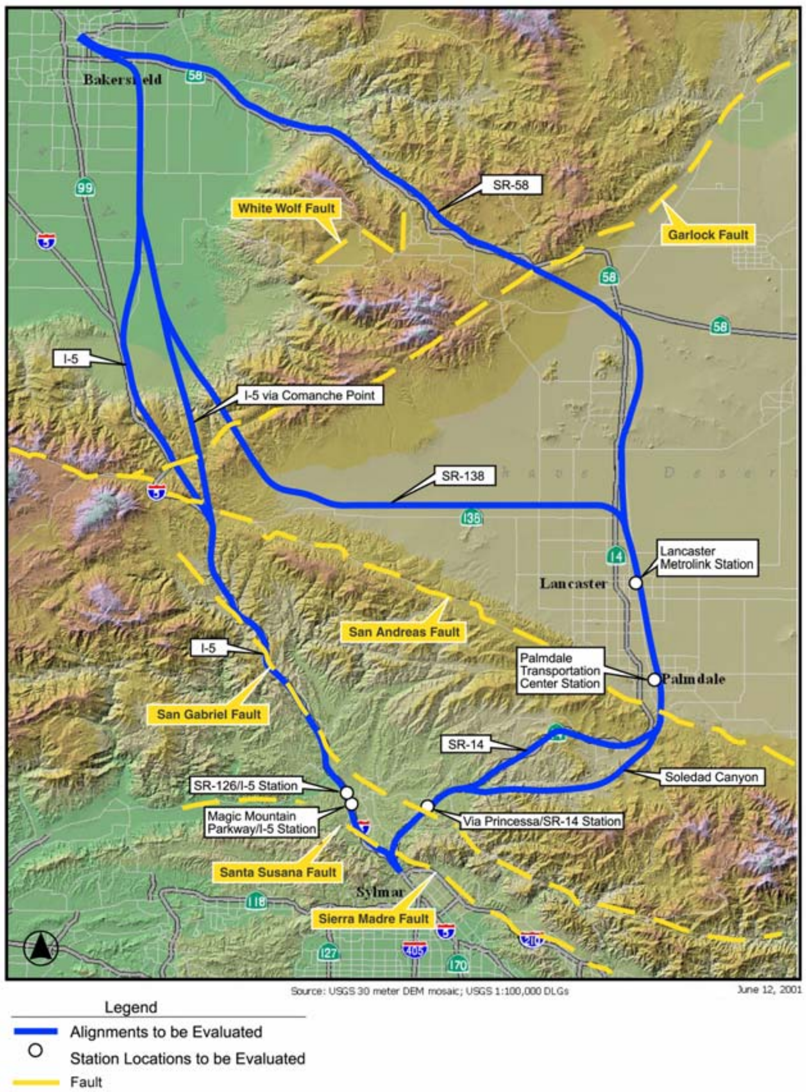

FIGURE 5-18: SIGNIFICANT FAULTS IN TEHACHAPI CROSSING

Figure 5-19 and 5-20 show an alignment option (HSR_13_18), which was constrained to the west of the I-5 to ensure only one crossing of a fault line. This alignment option crosses the San Andreas Fault zone at depth in tunnel with a single tunnel length of 13.7 miles.

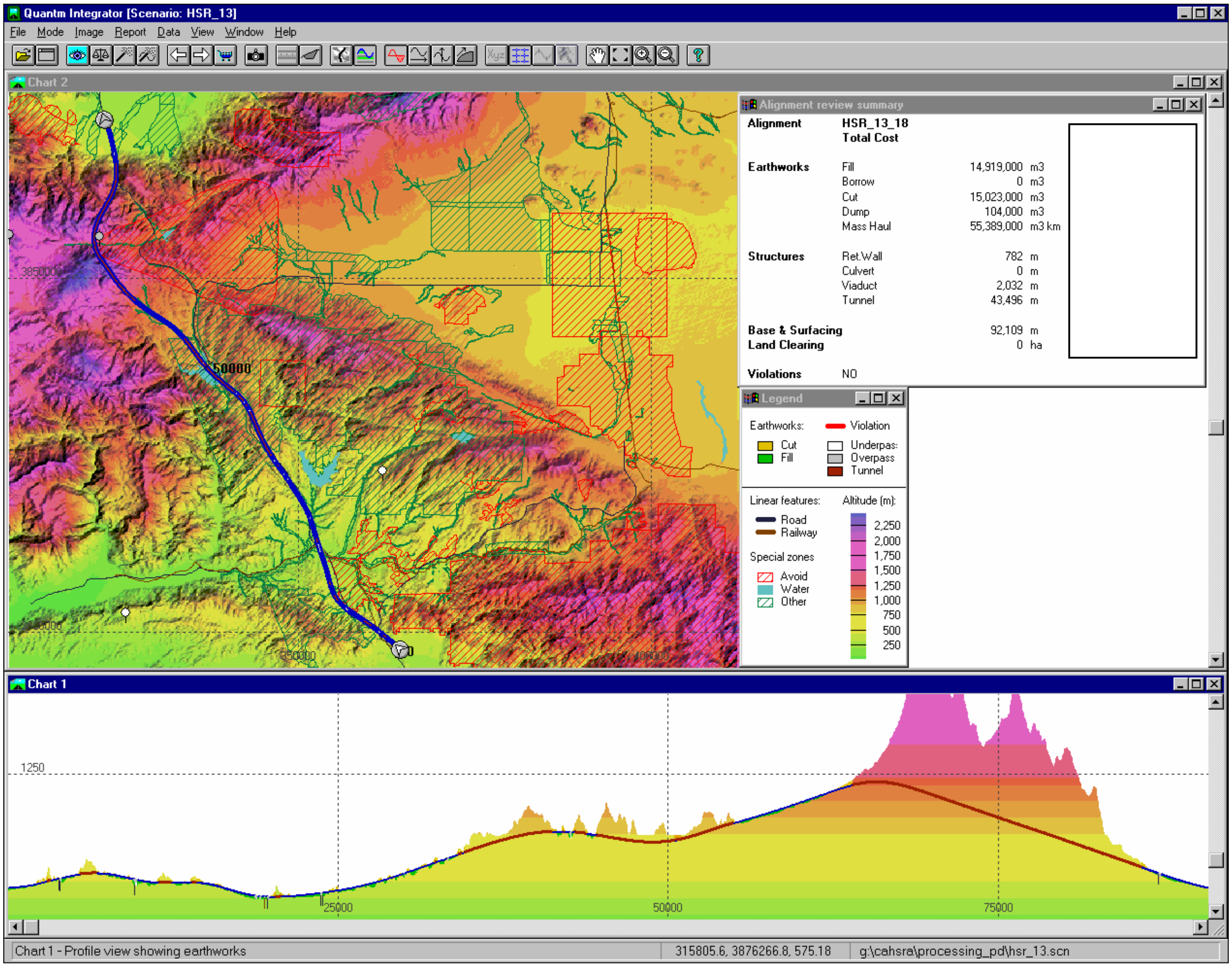

FIGURE 5-19: I-5 QUANTM ALIGNMENT TO WEST OF I-5 WITH ONE FAULT ZONE CROSSING

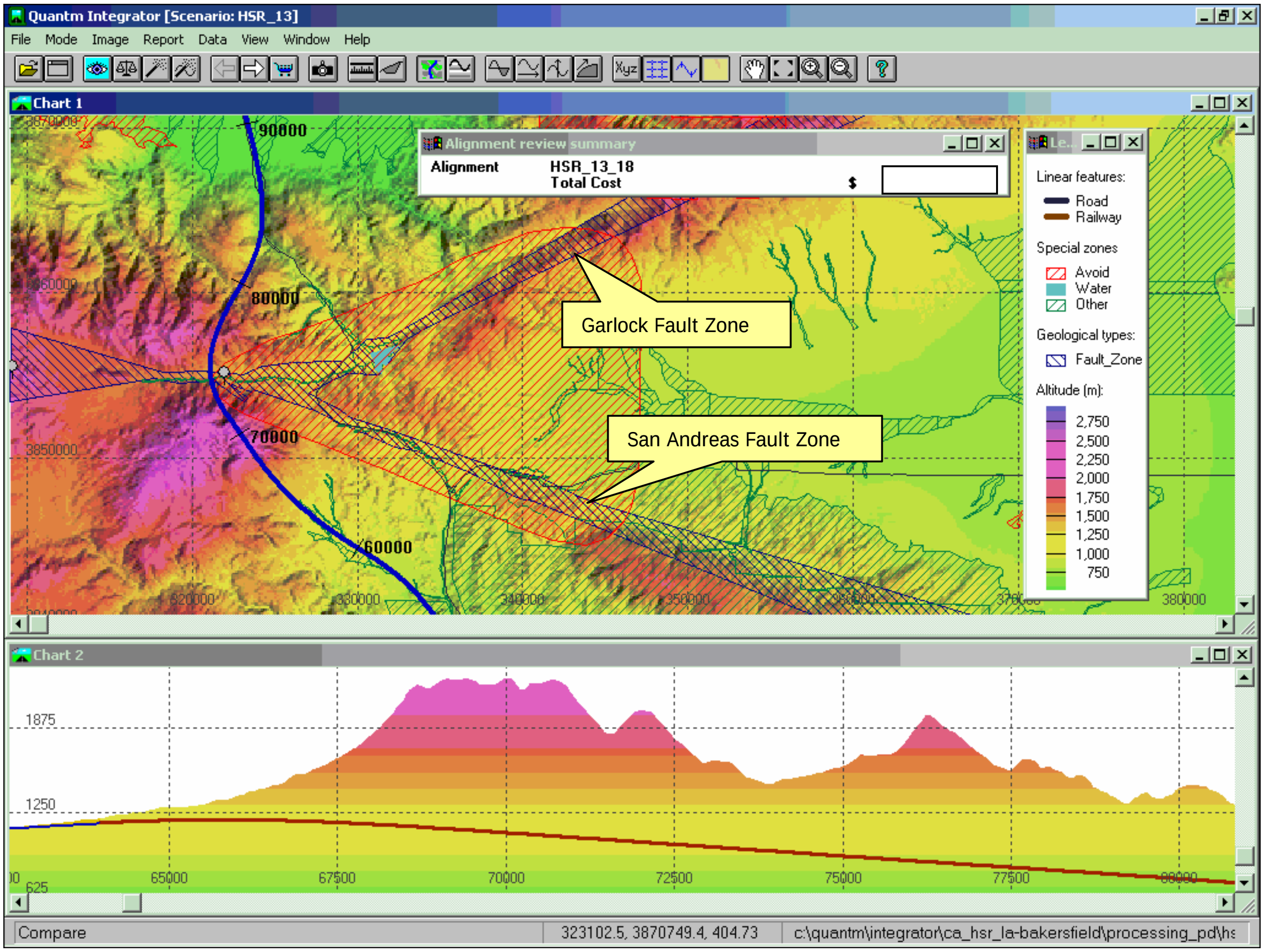

FIGURE 5-20: I-5 QUANTM ALIGNMENT TO WEST OF I-5 WITH ONE FAULT ZONE CROSSING

Figure 5-21 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. HSR_16_T_13 has an alignment construction cost of $2.96 billion and a maximum single tunnel length of 11.2 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 24.4% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 18.9%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

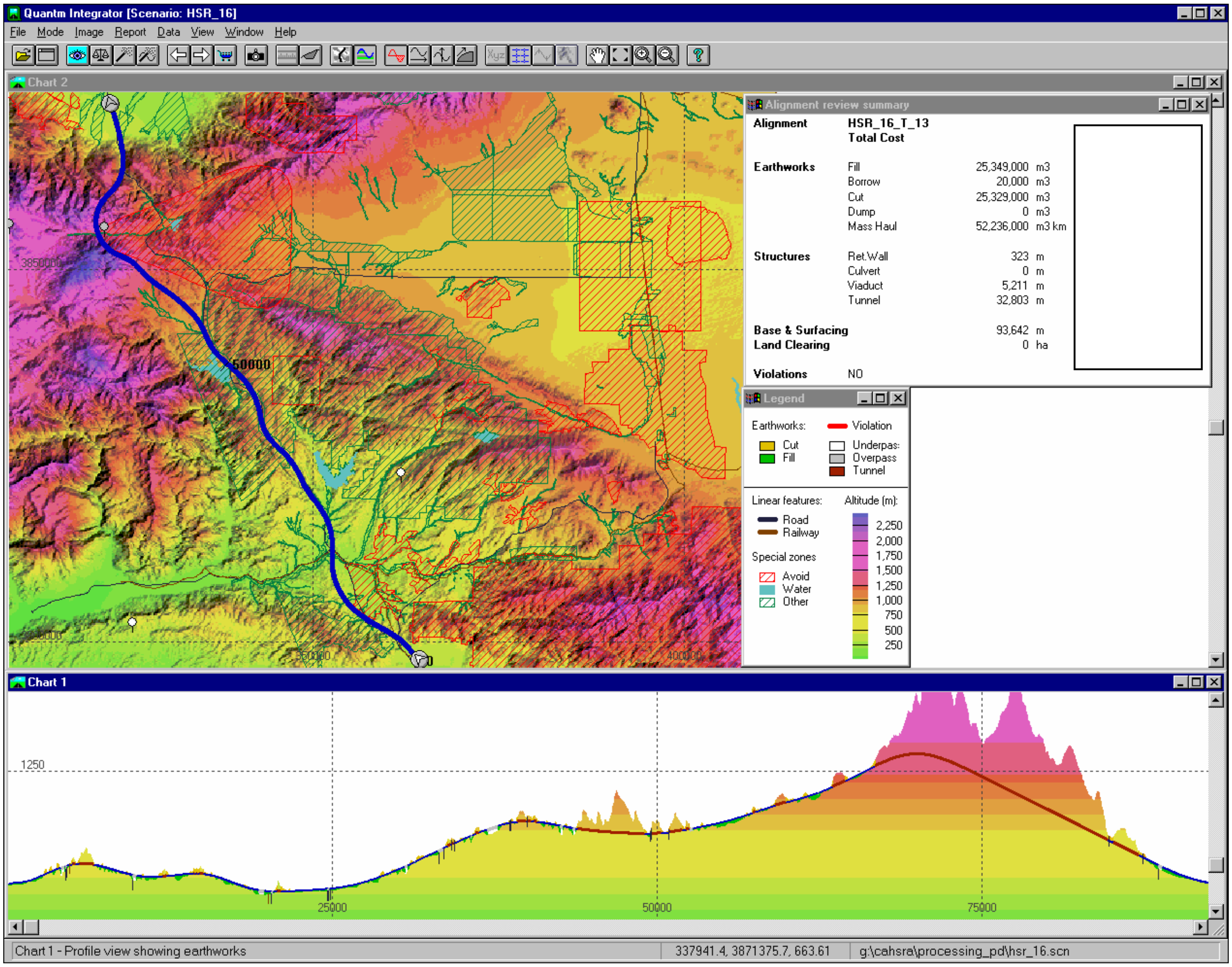

FIGURE 5-21: I-5 QUANTM ALIGNMENT TO WEST OF I-5 WITH ONE FAULT ZONE CROSSING (MAX. 5.0% GRADE 40M MAX CUT & FILL)

In the process of studying the possible options to minimize fault crossings in tunnel another possible solution was identified. This alignment option follows the general I-5 alignment up to the San Andreas Fault zone crossing and then proceeds to the east of the existing corridor. Using a 3.5% maximum grade, this particular alignment option allows for an at-grade crossing of the San Andreas Fault zone and an at grade or trenched crossing of the Garlock Fault zone. This alignment would require extensive construction in the floodplain area surrounding Castac Lake. The potential environmental impacts of this alignment option need to be further studied to assess the viability. This alignment alternative was not identified in the previous studies of this corridor.

Figure 5-22 and Figure 5-23 shows an alignment option (HSR_I5Bult_11_TI_9) which runs to the east of the I-5 allowing for at-grade crossings of both major fault zones. While this still crosses two faults, it crosses the faults at grade while keeping the tunnel lengths within the 6 miles maximum and maintaining the 3.5% maximum grade. The alignment construction cost is also the lowest of those identified for the I-5 corridor at $2.42 billion a 45% reduction on the Original I-5 alignment.

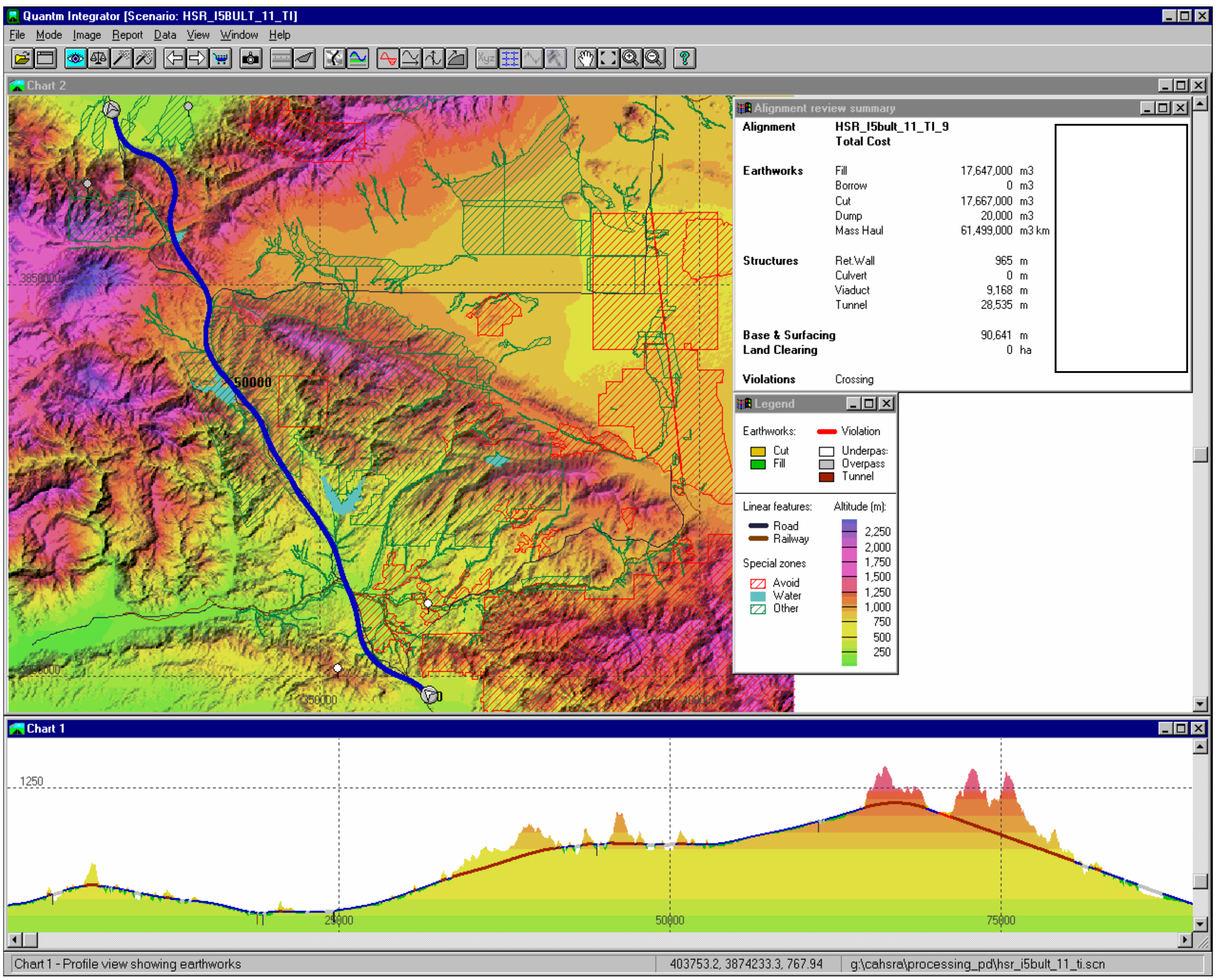

FIGURE 5-22: I-5 QUANTM ALIGNMENT TO EAST OF I-5 CORRIDOR, CROSSING FAULT LINES AT GRADE

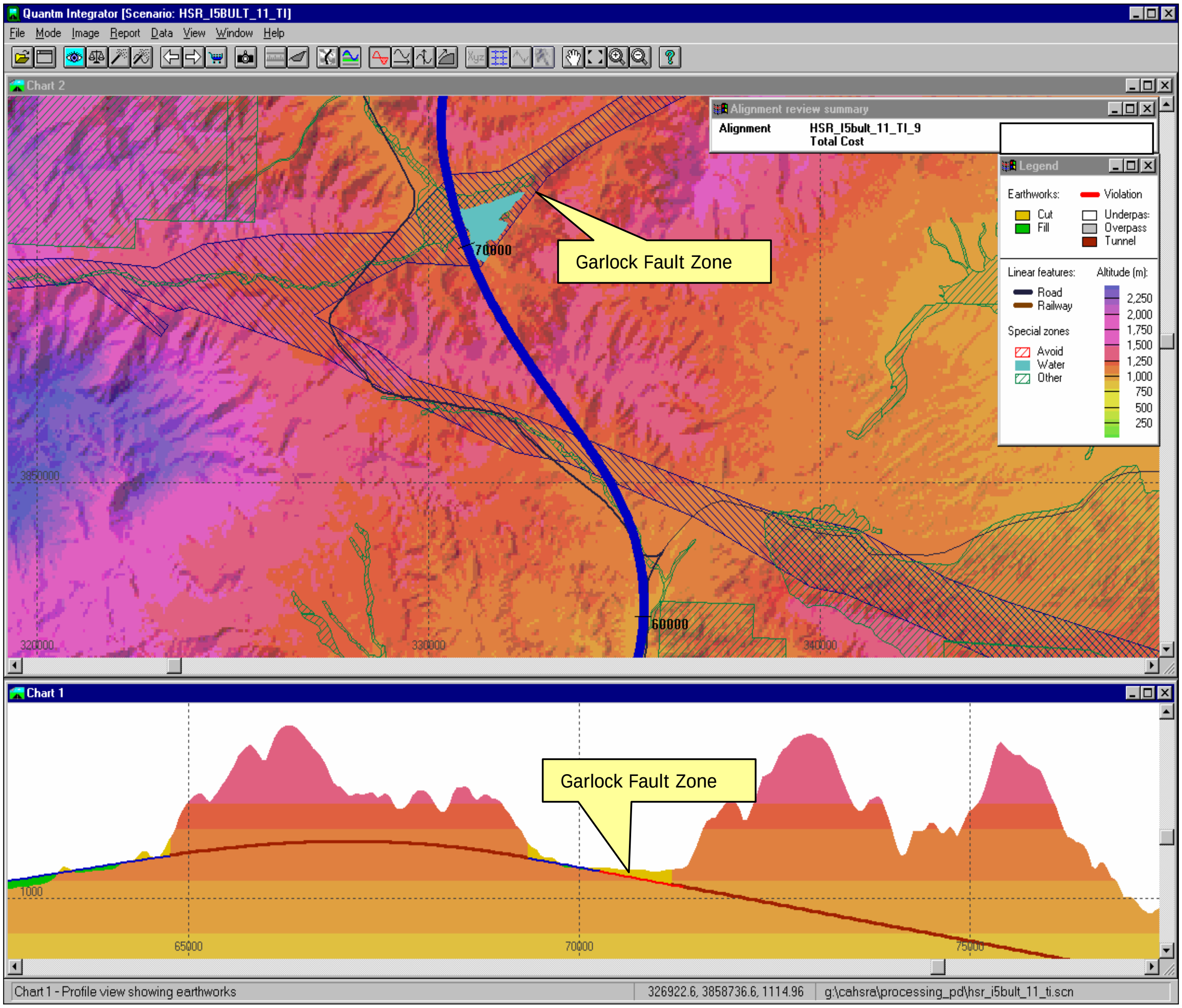

FIGURE 5-23: I-5 QUANTM ALIGNMENT TO EAST OF I-5 CORRIDOR, CROSSING FAULT LINES AT GRADE

Figure 5-24 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. HSR_I5BULT_11_9T_7 has an alignment construction cost of $2.18 billion and a maximum single tunnel length of 4.6 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 24.3% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 9.9%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

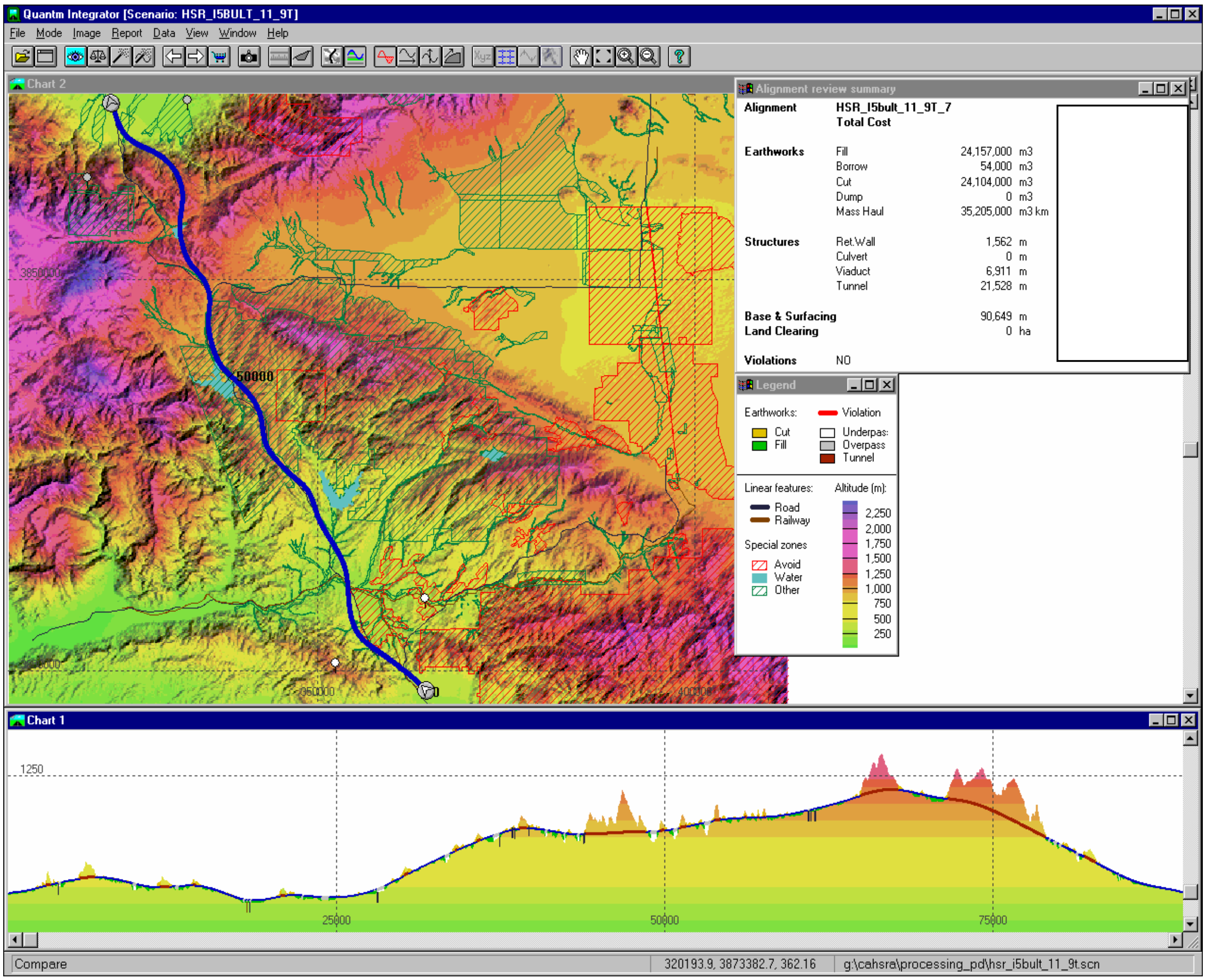

FIGURE 5-24: I-5 QUANTM ALIGNMENT TO EAST OF I-5 CORRIDOR, CROSSING FAULT LINES AT GRADE (MAX. 5.0% GRADE 40M MAX CUT & FILL)

TABLE 5-4: I-5/GRAPEVINE ALIGNMENT COMPARISON SUMMARY

Alignment	Total Length	Total Tunnel Length	Maximum Tunnel Length	Alignment Construction Cost (billions)
Screening Alignment Option (Original Alignment~I5ALTBULT~seed)	55.2 miles	34.4 miles	14.3 miles	$4.48
Refined Alignment Option – Minimize Tunnels & Cost (Quantm - HSR_I5bult_04_T_1)	56.2 miles	21.6 miles	10.6 miles	$2.93
Refined Alignment Option – Minimize Tunnels & Cost Max Grade 5.0% (Quantm – I5_100_T_3)	56.0 miles	13.2 miles	4.3 miles	$1.99
Refined Alignment Option - Minimize Tunnels & Cost (Quantm - HSR_I5bult_04_T_5)	55.9 miles	22.4 miles	9.3 miles	$3.04
Screening Alignment Option Max Grade 2.5% (Original Alignment~I5ALTA~SEED)	55.1 miles	42.4 miles	19.2 miles	$5.36
Refined Alignment Option - Minimize Tunnel & Cost Max Grade 2.5% (Quantm - HSR_I5_11_V_12)	55.1 miles	34.8 miles	14.7 miles	$4.55
New Alignment Option - Crossing Single Fault Zone West of I-5 (Quantm - HSR_13_18)	57.2 miles	27 miles	13.7 miles	$3.65
New Alignment Option - Crossing Single Fault Zone West of I-5 Max Grade 5.0% (Quantm - HSR_16_T_13)	58.2 miles	20.4 miles	11.2 miles	$2.96
New Alignment Option - Crossing Major Fault Zones At-Grade East of I-5 (Quantm – HSR_I5bult_11_TI_9)	56.3 miles	17.7 miles	6.0 miles	$2.42
New Alignment Option - Crossing Major Fault Zones At-Grade East of I-5 Max Grade 5.0% (Quantm - HSR_I5bult_11_9T_7)	56.3 miles	13.4 miles	4.6 miles	$2.18

5.2.2 SR-58 / Mojave

This corridor was investigated in sections: the southern section from Sylmar to Palmdale, the middle section through Palmdale and Lancaster, and the northern section from Lancaster to the Central Valley floor. The middle section is highly constrained due to existing development and transportation corridors. The northern and southern sections were studied more extensively because of the potential for refinement in the mountainous terrain.

A. Screening alignment option – southern section (Soledad Canyon)

Two separate alignment options have been considered in the screening evaluation for the southern section: one along Soledad Canyon and one along SR-14. The screening alignment option for the southern route along Soledad Canyon (SR58South~Seed) is shown in Figure 5-25. South of Soledad Canyon, alignment is constrained by extensive development along the SR-14 corridor. Through Soledad Canyon the alignment was placed in tunnel to avoid the environmentally sensitive areas of Soledad Canyon.

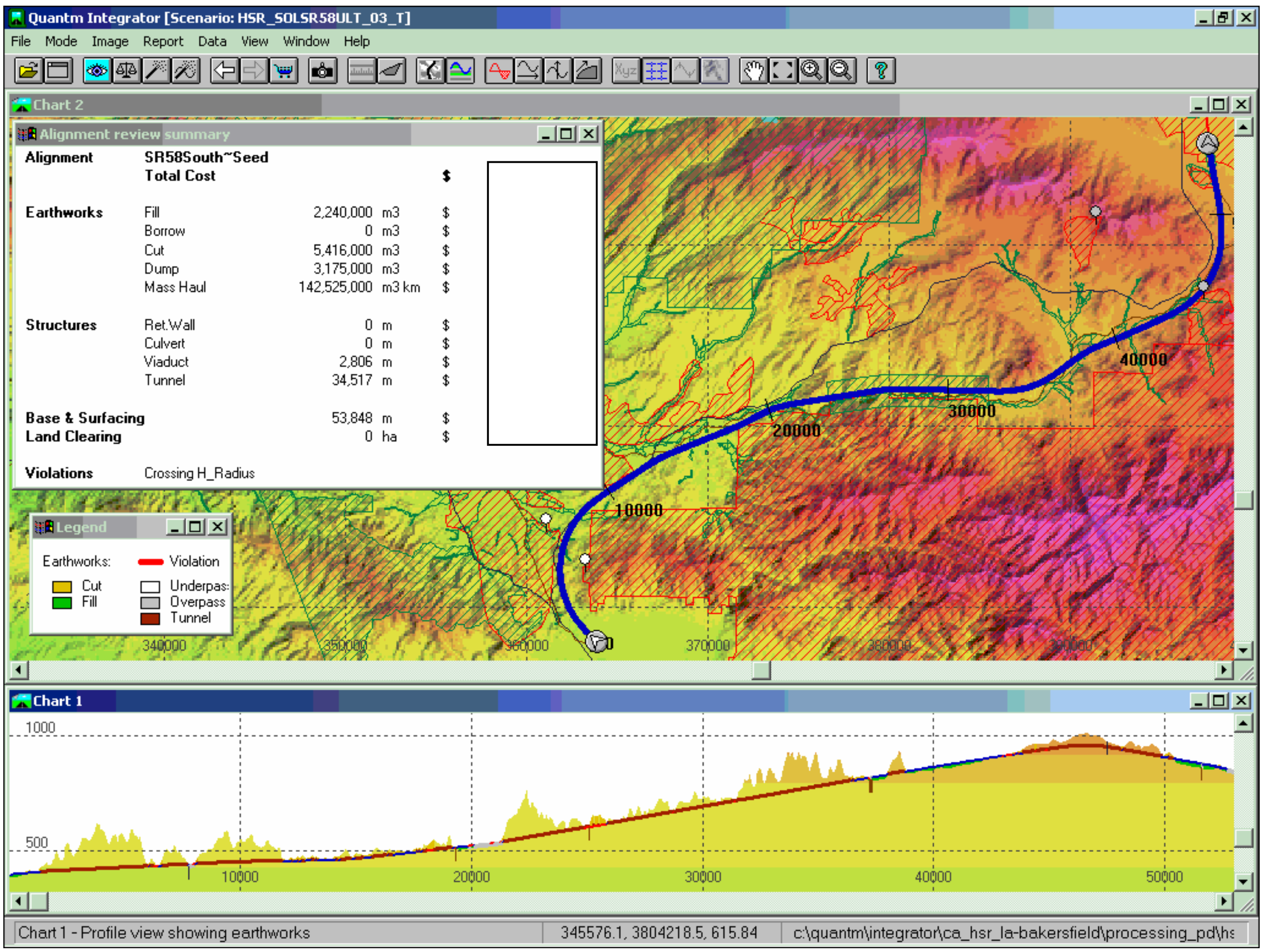

FIGURE 5-25: SOLEDAD CANYON - SCREENING ALIGNMENT – (WITH TUNNEL CONSTRAINTS)

B. Quantm Derived Alignment – Southern Section (Soledad Canyon with tunnel)

The study team used the Quantm system to investigate alignments that met the tunnel constraint through the environmentally sensitive areas of Soledad Canyon. While the construction cost has been substantially reduced, the constraint results in a continuous tunnel of more than 9 miles.

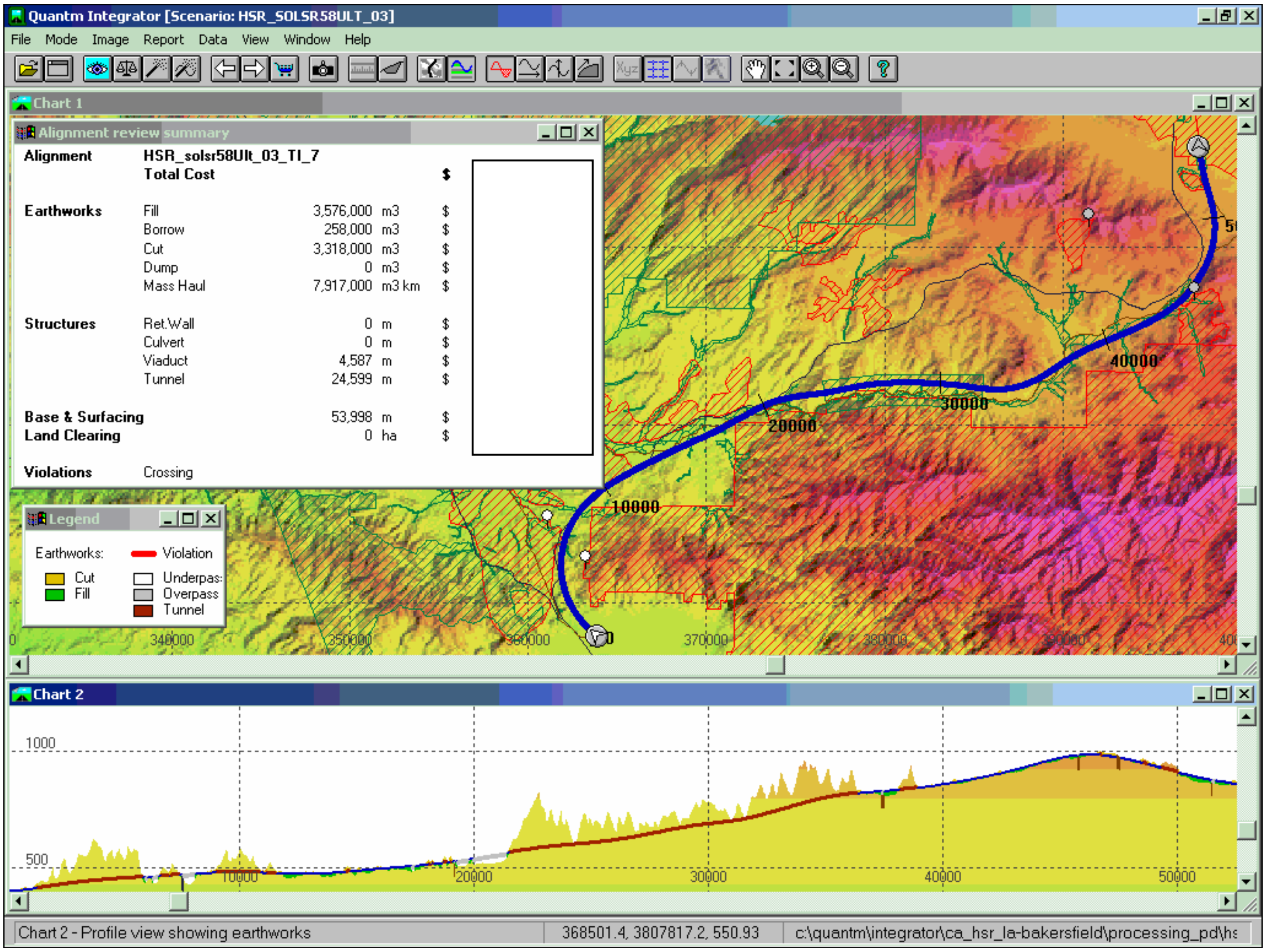

FIGURE 5-26: SOLEDAD CANYON - QUANTM ALIGNMENT WITH TUNNEL CONSTRAINT (MAX. 3.5% GRADE)

C. Screening alignment option – southern section (Soledad Canyon without tunnel)

Previous studies have considered alignments for an alternative scenario where there is not a requirement to traverse the Soledad Canyon in tunnel. The result was a reduction in continuous tunnel length to 3.4 miles and an alignment construction cost of $2.17 billion. The potential impacts to the environmentally sensitive areas around the Santa Clara River will need to be considered.

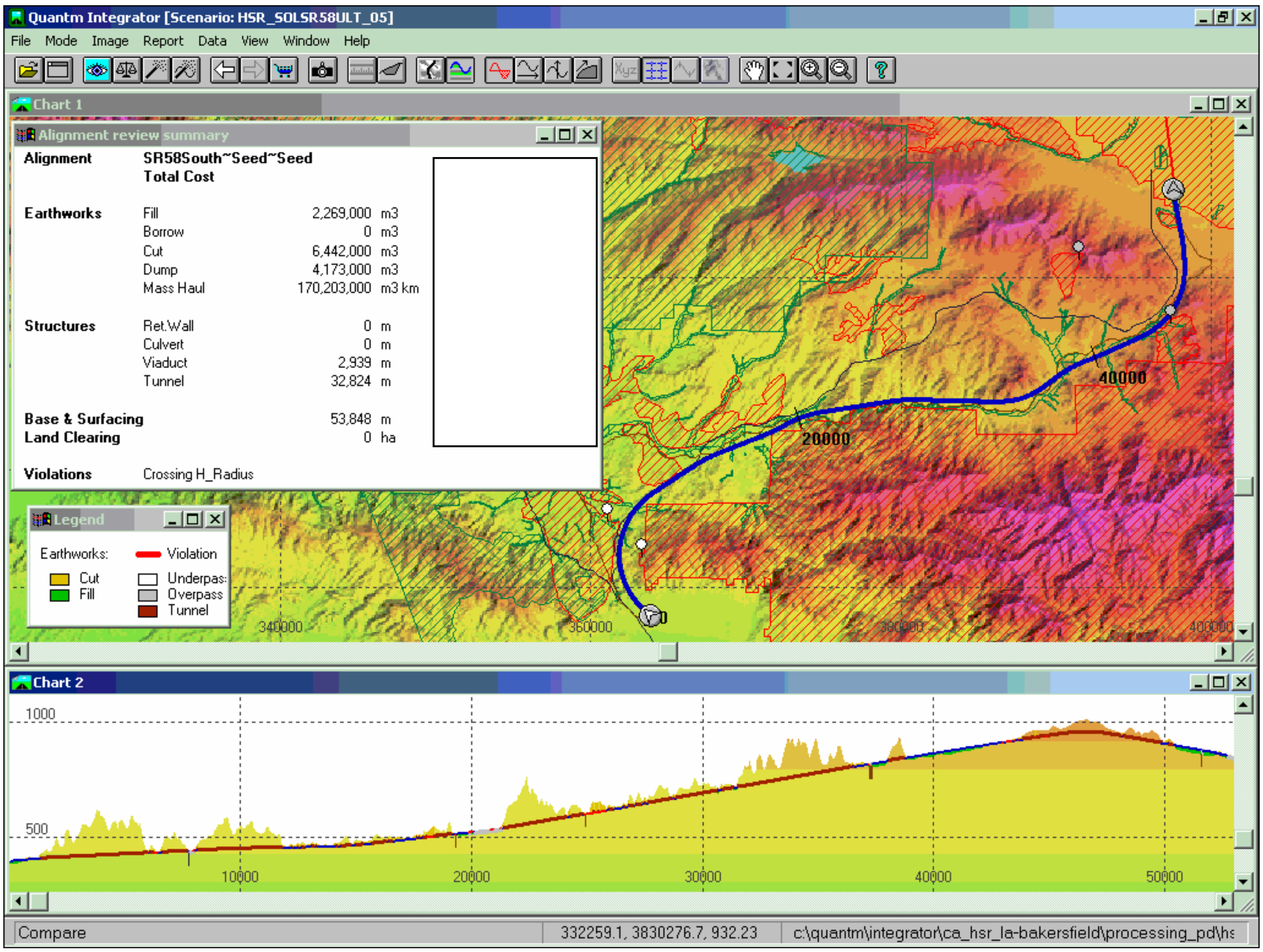

FIGURE 5-27: SOLEDAD CANYON - SCREENING ALIGNMENT – (WITHOUT TUNNEL CONSTRAINT)

D. Quantm Derived Alignment – Southern Section (Soledad Canyon without tunnel)

The alignment investigation was constrained within the Soledad Canyon. Figure 5-28 shows an alignment option (HSR_SOLSR58Ult_05_TI_11) that, in comparison to the screening alignment, has reduced the total tunnel length from 20.4 to 11.1 miles and cut the construction cost to $1.32 billion, a 37% reduction. Maximum continuous tunnel is now 3.1 miles.

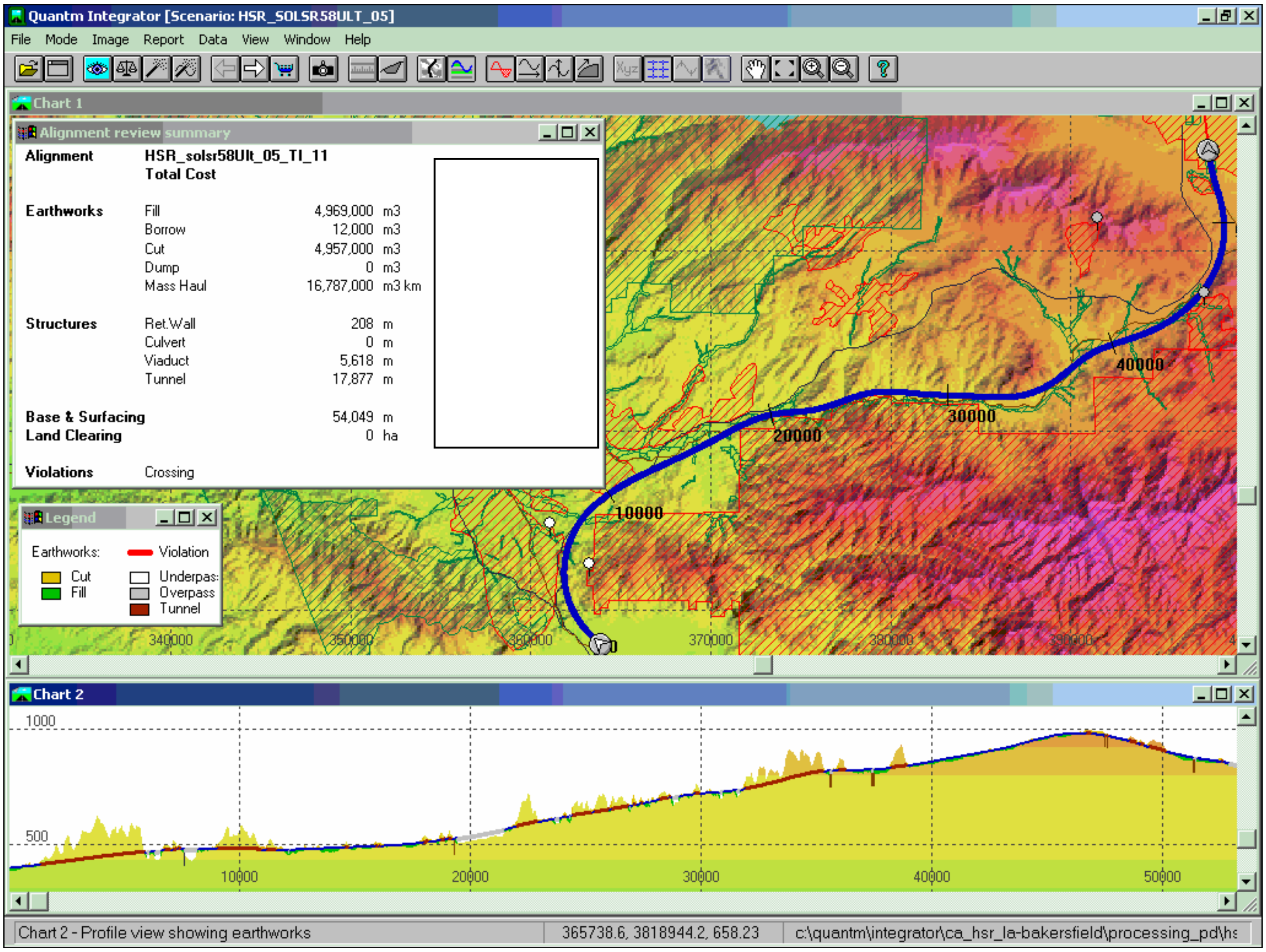

FIGURE 5-28: SOLEDAD CANYON - QUANTM ALIGNMENT WITHOUT TUNNEL CONSTRAINT (MAX. 3.5% GRADE)

E. Quantm Derived Alignment – Southern Section (Soledad Canyon without tunnel and increased cut & fill limits)

The maximum cut and fill height allowed before imposing a structure was increased from 20m to 40m to replicate previous studies undertaken to minimize tunnels. Figure 5-29 shows an alignment option (HSRSOLSR58Ult_07_T_4) that has reduced the total tunnel length to 5.2 miles and cut the construction cost to $905 million. This represents a $414 million or 31% reduction on the alignment that was constrained to 20m cut and fill. Since the studies undertaken to minimize tunnels were done using different terrain data, there is no benchmark cost available for this option.

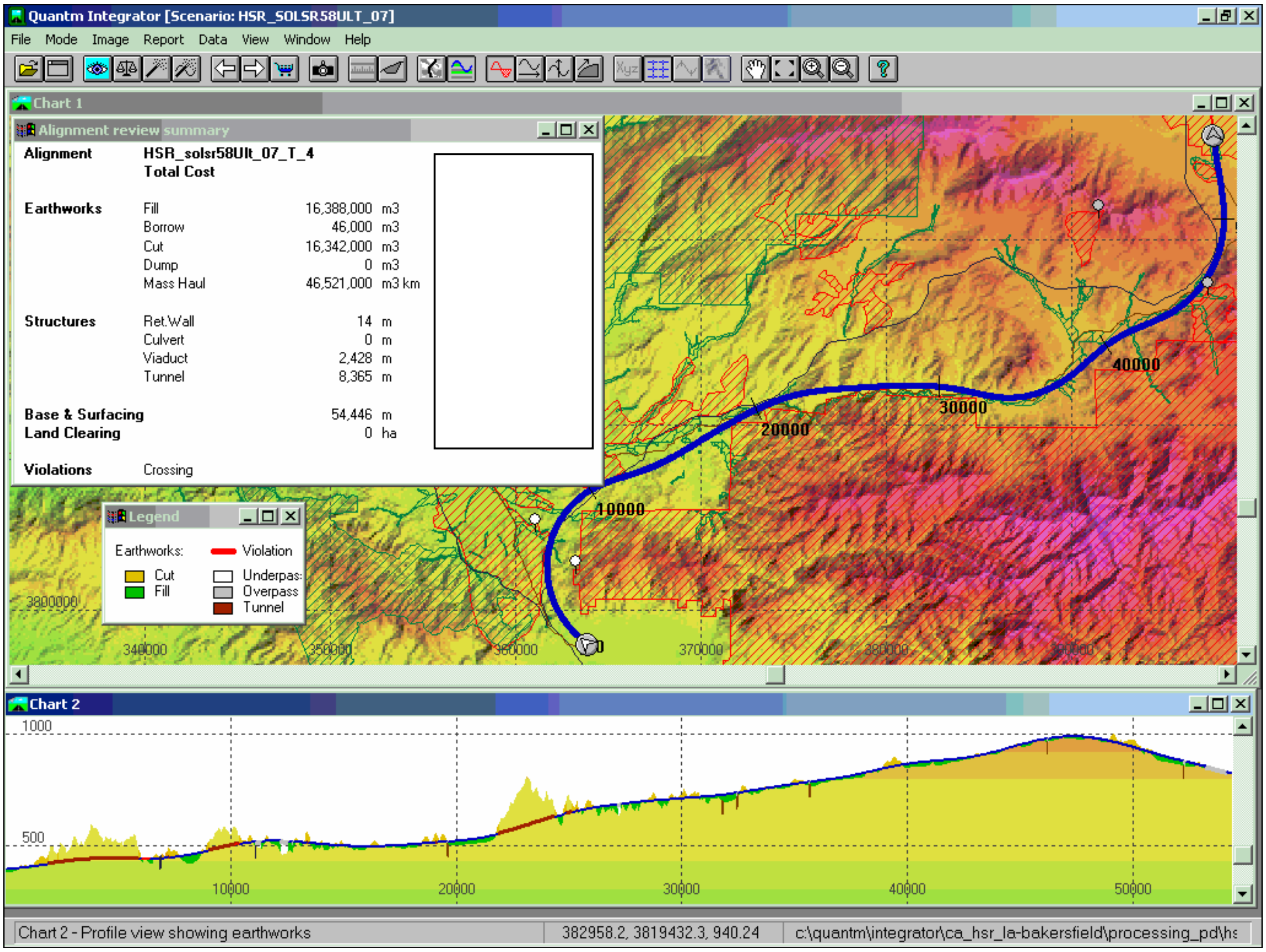

FIGURE 5-29: SOLEDAD CANYON - QUANTM ALIGNMENT WITHOUT TUNNEL CONSTRAINT AND 40M MAX. CUT & FILL (MAX. 3.5% GRADE)

Figure 5-30 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. HSR_SOLSR58ULT_07_4T_13 has an alignment construction cost of $844 million and a maximum single tunnel length of 2.8 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 5.8% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 7.7%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

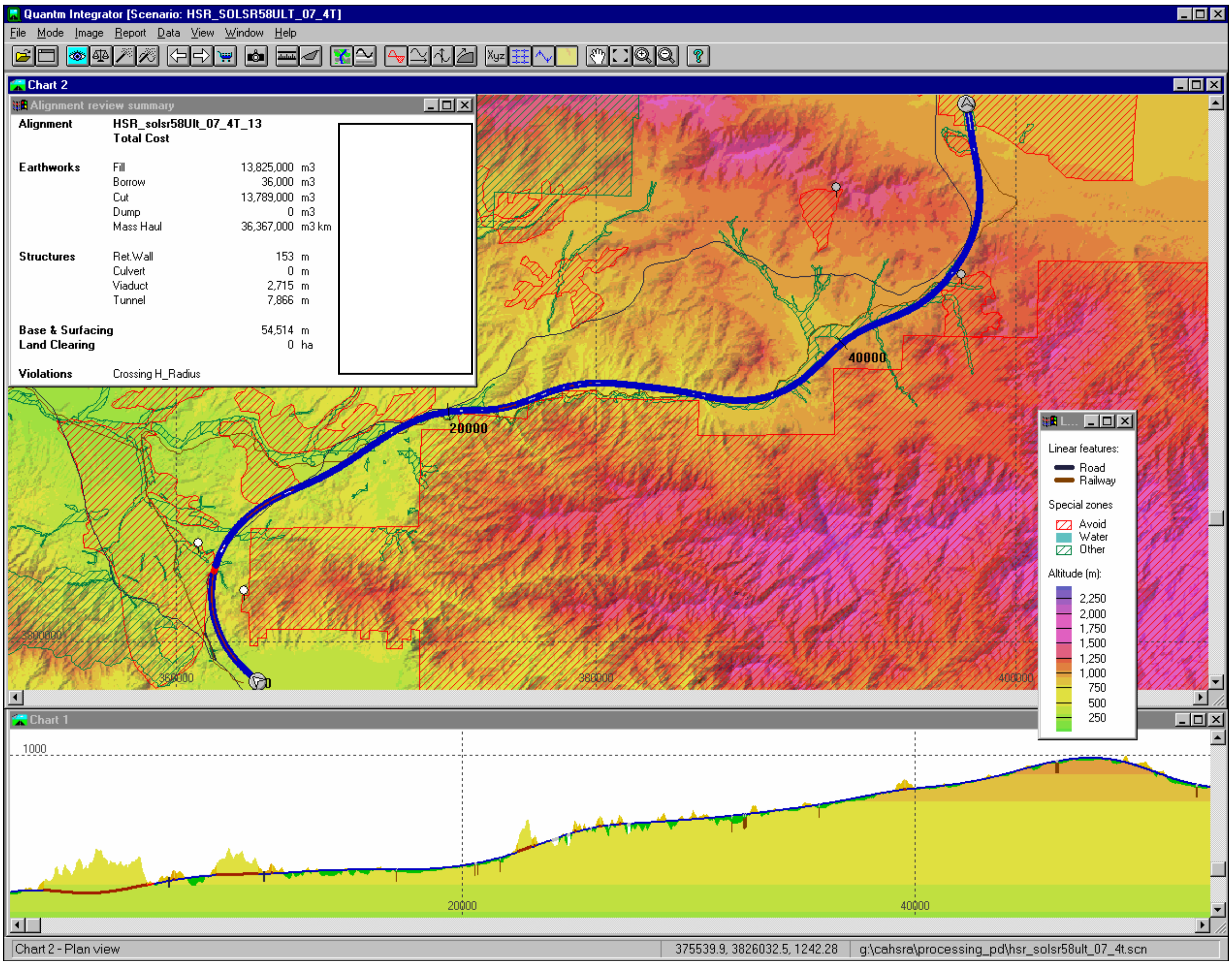

FIGURE 5-30: SOLEDAD CANYON - QUANTM ALIGNMENT WITHOUT TUNNEL CONSTRAINT AND 40M MAX. CUT & FILL (MAX. 5.0% GRADE)

F. Quantm Derived Alignment – Southern Section (Alternative)

The study team also investigated other alternative alignments, constraining it with the urban development, river crossings and sensitive environmental areas established in the screening option. Figure 5-31 shows an alignment option (HSR_SOLSR58Ult_03_T_18) with a construction cost of $1.27 billion, a 40% reduction over the Soledad Canyon screening alignment option. This alignment falls in between the alignment options previously studied on along Soledad Canyon and SR-14.

While this alignment meets all of the defined constraints (including the Santa Clarita to Palmdale corridor), it should be noted that it would need further environmental consideration as it runs outside the area that has previously been investigated. In particular, the potential impacts to the community of Acton must be considered.

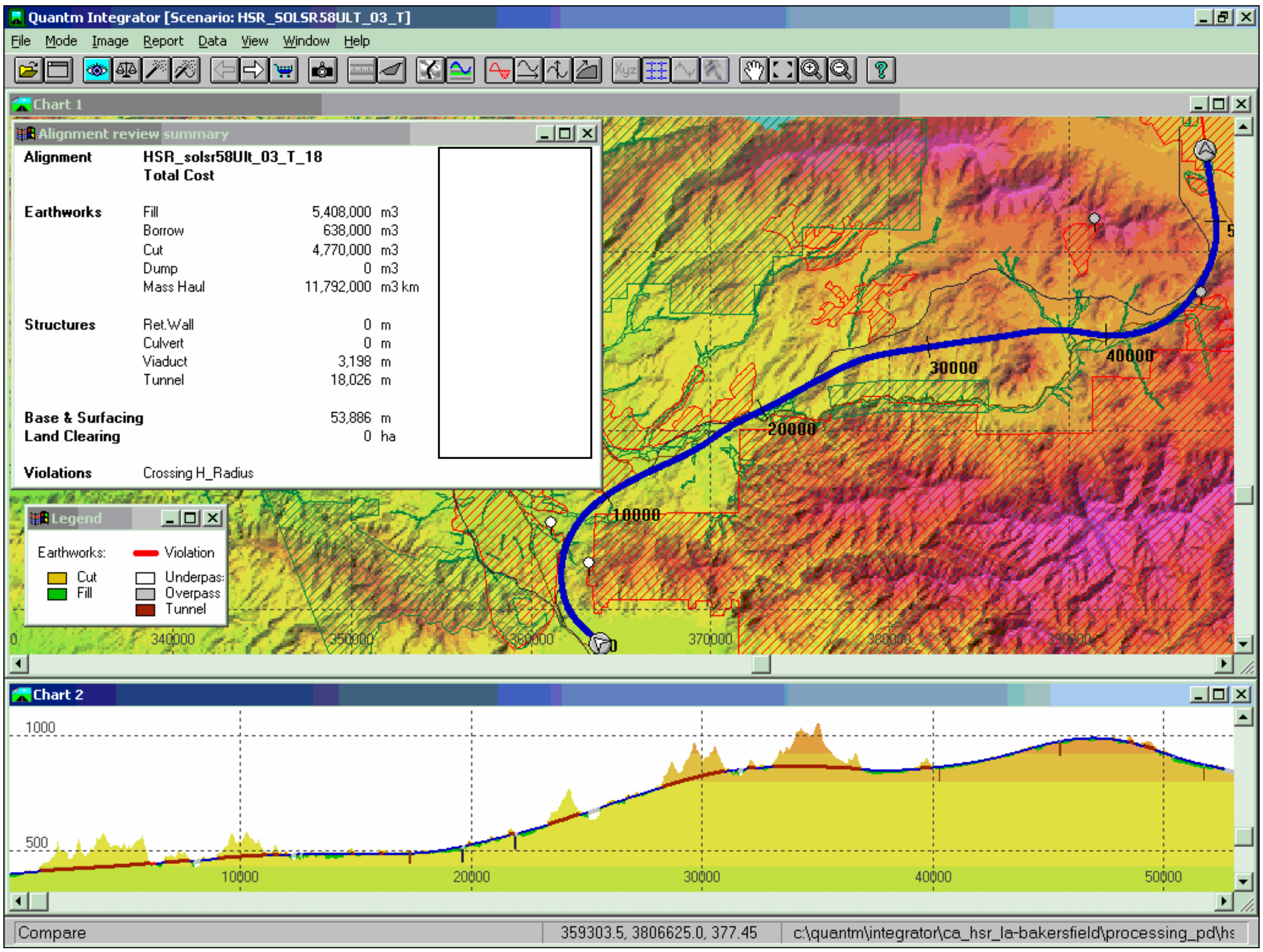

FIGURE 5-31: SOUTHERN - ALTERNATIVE QUANTM ALIGNMENT (MAX. 3.5 % GRADE)

G. Screening alignment option – southern section (SR-14)

The SR-14 corridor has been considered as an alternative means to cross the Mojave. Figure 5-32 shows the screening alignment with total tunneling of 20 miles and a construction cost of $2.14 billion.

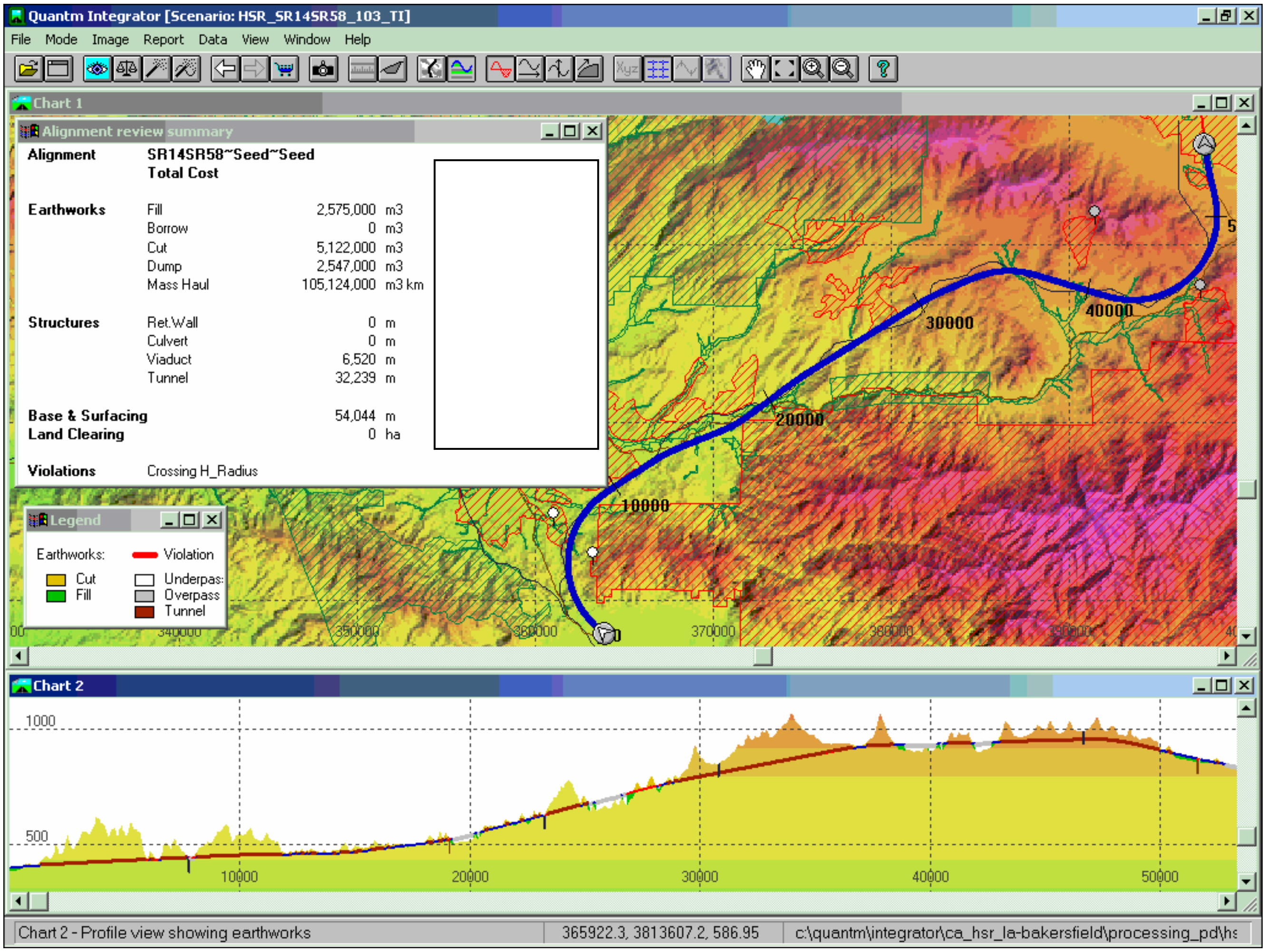

FIGURE 5-32: SR-14 - SCREENING ALIGNMENT

H. Quantm Derived Alignment – Southern Section (SR-14)

Due to existing and planned development as well as terrain, the investigation was constrained to consider alternatives in close vicinity to the SR-14 and the existing alignment. Figure 5-33 shows an alignment (HSR_SR14SR58_103_TI_19) that has reduced the total tunnel length to 13.4 miles and the construction cost to $1.52 billion, a 29% reduction.

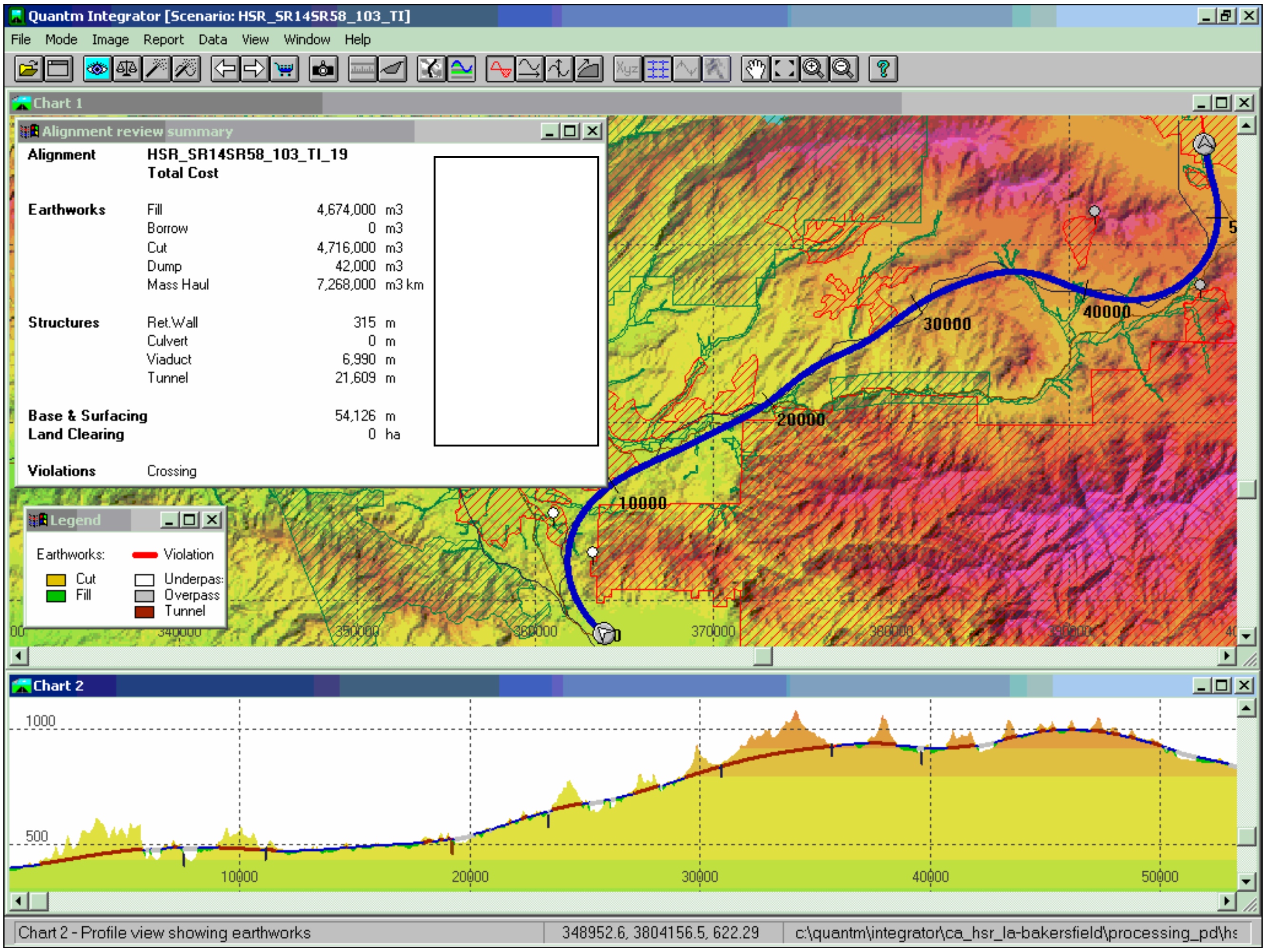

FIGURE 5-33: SR-14 - QUANTM ALIGNMENT (MAX. 3.5% GRADE)

I. Quantm Derived Alignment – Southern Section (SR-14 With increased cut & fill limits)

To be consistent with previous studies undertaken to minimize tunneling, Quantm tests were run with maximum cut and fill heights of 40m. Figure 5-34 shows a Quantm derived alignment option demonstrating significant reduction in tunneling requirements and alignment costs.

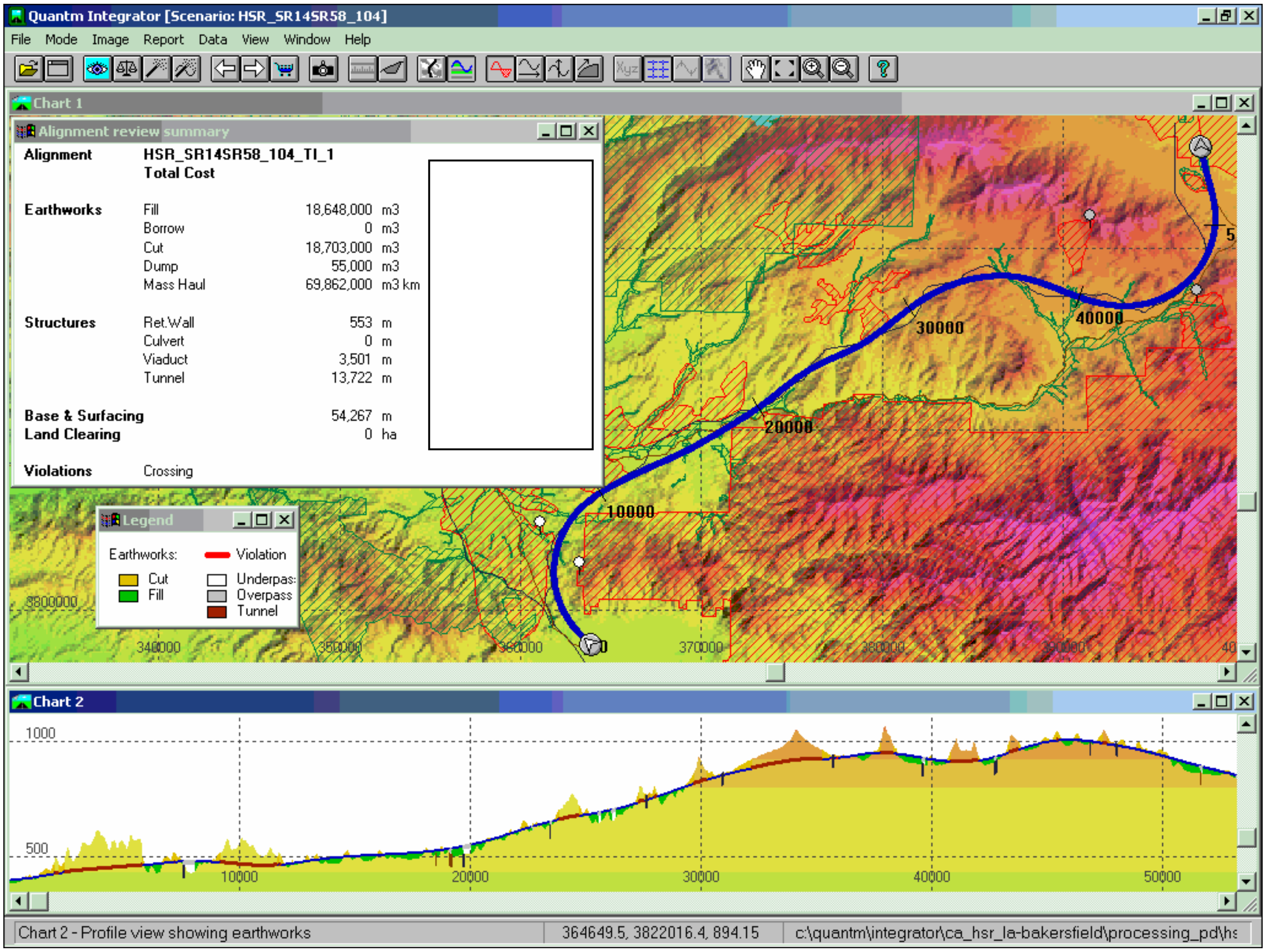

FIGURE 5-34: SR-14 - QUANTM ALIGNMENT (TOTAL INTENSIVE REFINEMENT WITH MAX. 3.5% GRADE AND 40M MAX. CUT & FILL)

Figure 5-35 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. HSR_SR14SR58_104_7T_3 has an alignment construction cost of $1.04 billion and a maximum single tunnel length of 2.6 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 22.4% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 17.5%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

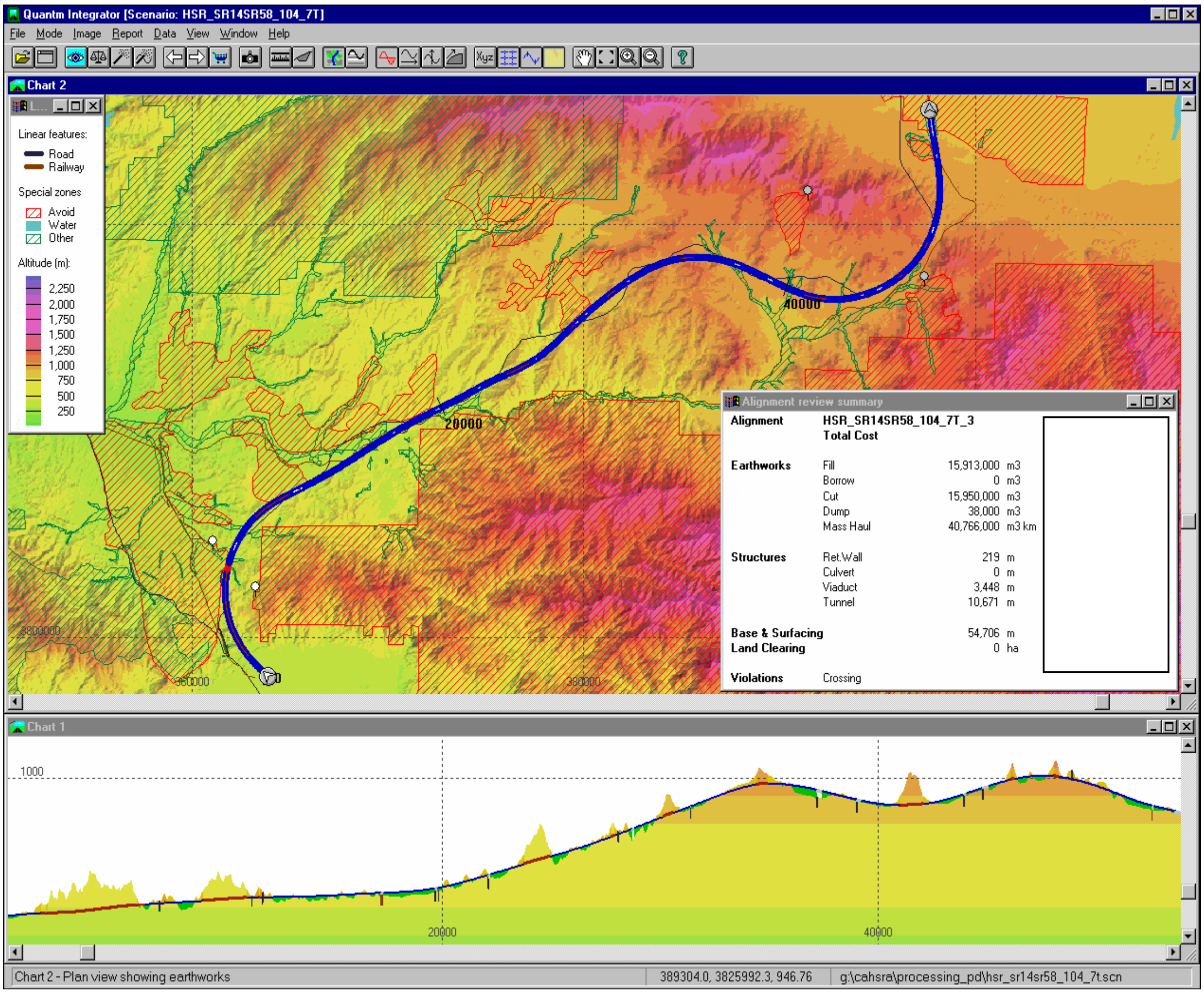

FIGURE 5-35: SR-14 - QUANTM ALIGNMENT (TOTAL INTENSIVE REFINEMENT WITH MAX. 5.0 % GRADE AND 40M MAX. CUT & FILL)

5.2.2.1 NORTHERN SECTION

A. Screening alignment option – Northern section (2.8% Maximum Grade)

The screening alignment option for the northern route along SR-58 (SR58North~Seed~Seed) is shown in Figure 5-36. This alignment includes a 12 miles continuous segment of tunnel and a construction cost of $3.27 billion.

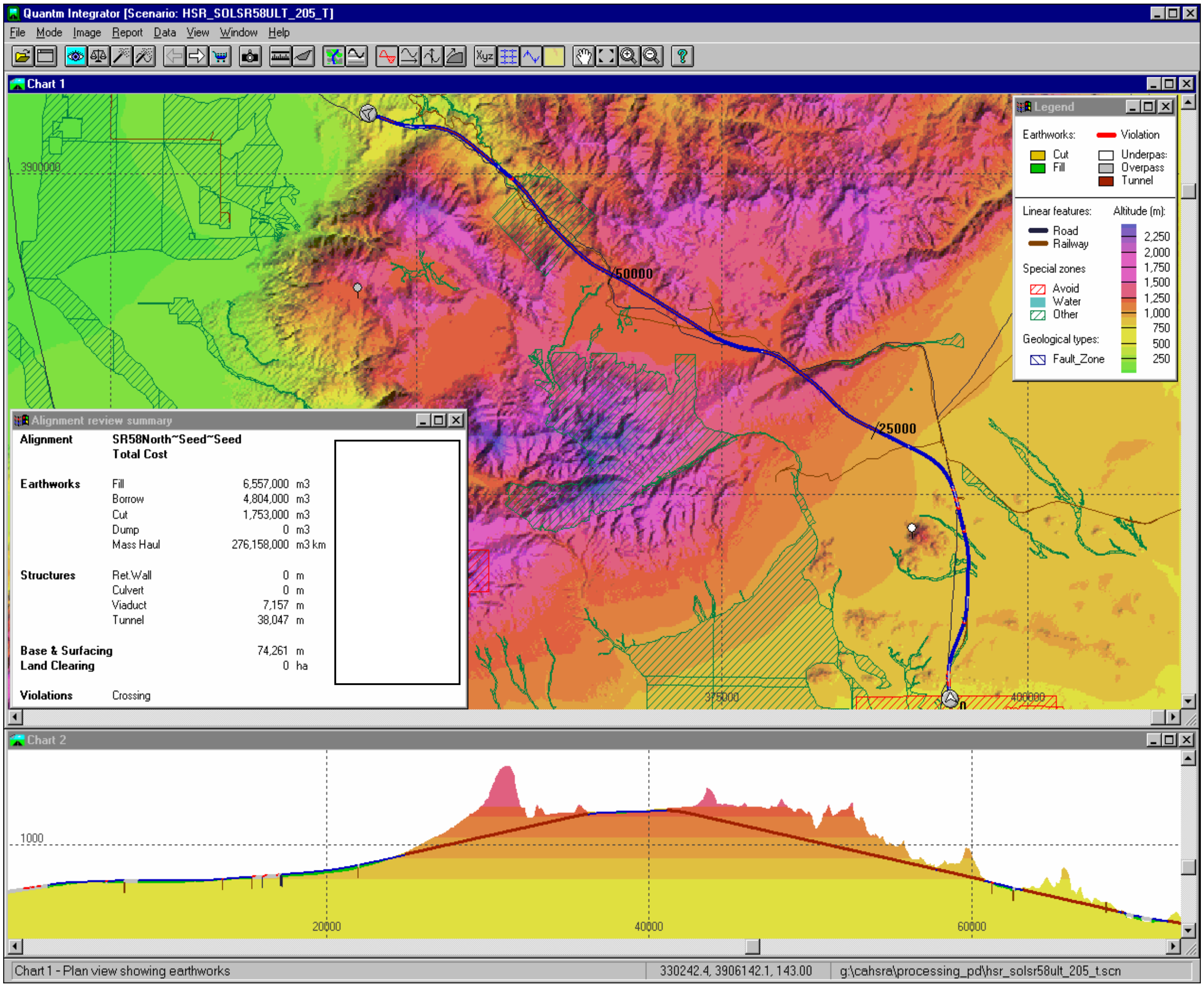

FIGURE 5-36: SR-58 - SCREENING ALIGNMENT – NORTHERN SECTION (MAX. 2.8% GRADE)

B Quantm Derived alignment – Northern section (2.8% Max. grade)

The investigation of alternative alignments in the northern section was constrained within the known constraints along the SR-58 corridor between the northern Antelope Valley and the Central Valley floor.

Figure 5-37 shows an alignment option (HSR_SOLSR58Ult_205_T_10) using a maximum grade of 2.8% that has 9.6 miles of tunneling with a construction cost of $1.33 billion, a 59% reduction. The maximum continuous tunnel length in this alignment is 3.8 miles.

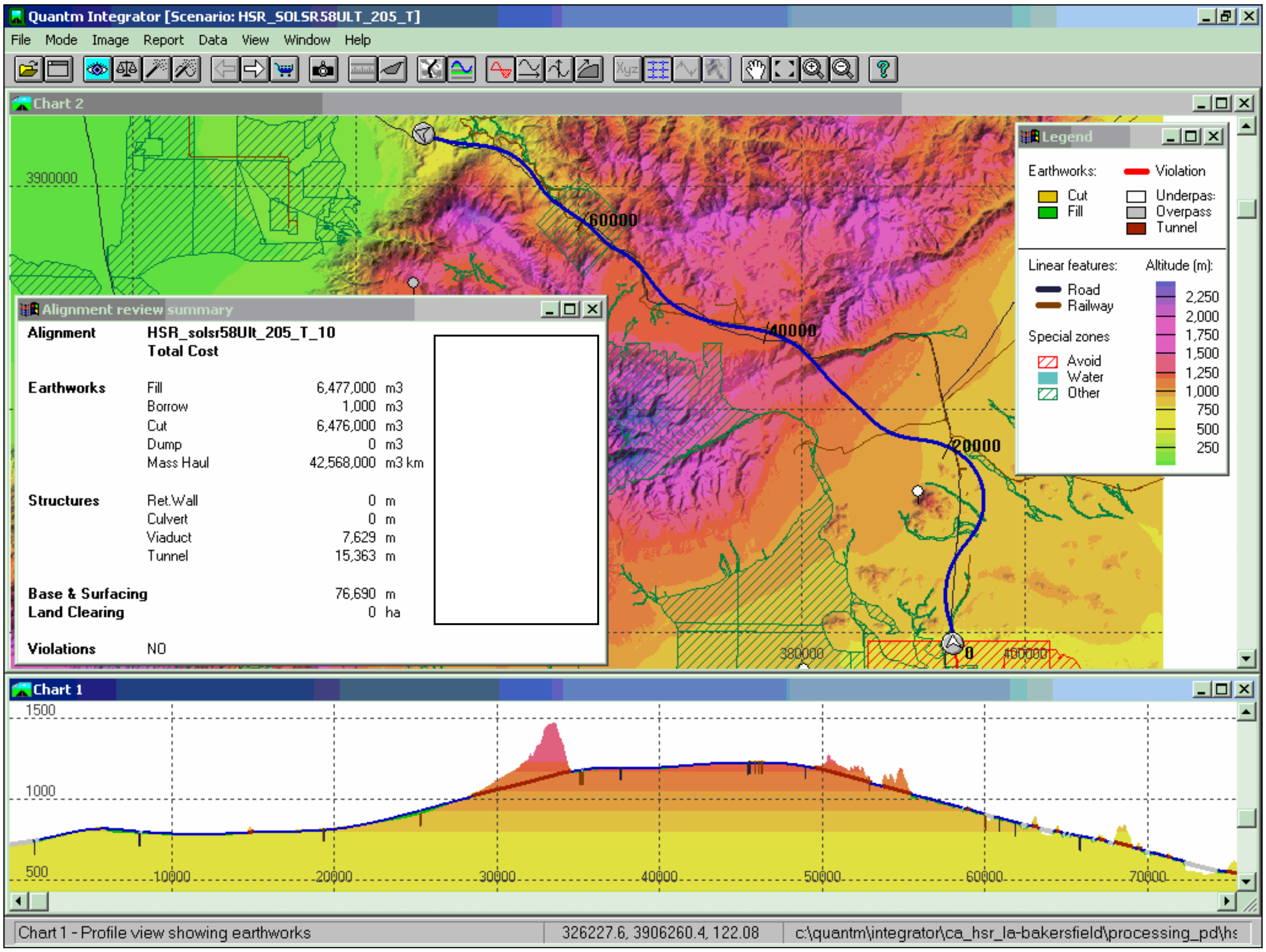

FIGURE 5-37: SR-58 - QUANTM ALIGNMENT – NORTHERN SECTION MAX. 2.8% GRADE WITH 40M MAX. CUT & FILL

C. Quantm Derived alignment – Northern section (3.5% Max. grade)

Figure 5-38 shows the result of sensitivity analysis to determine construction impact of a variance of the maximum grade to 3.5%. The result of the grade change (HSR_SOLSR58Ult_201_T_6) is a reduction in total tunnel length of 1 mile and a reduction in construction cost of $110 million, to $1.22 billion. The maximum single tunnel length in this alignment is 3.1 miles.

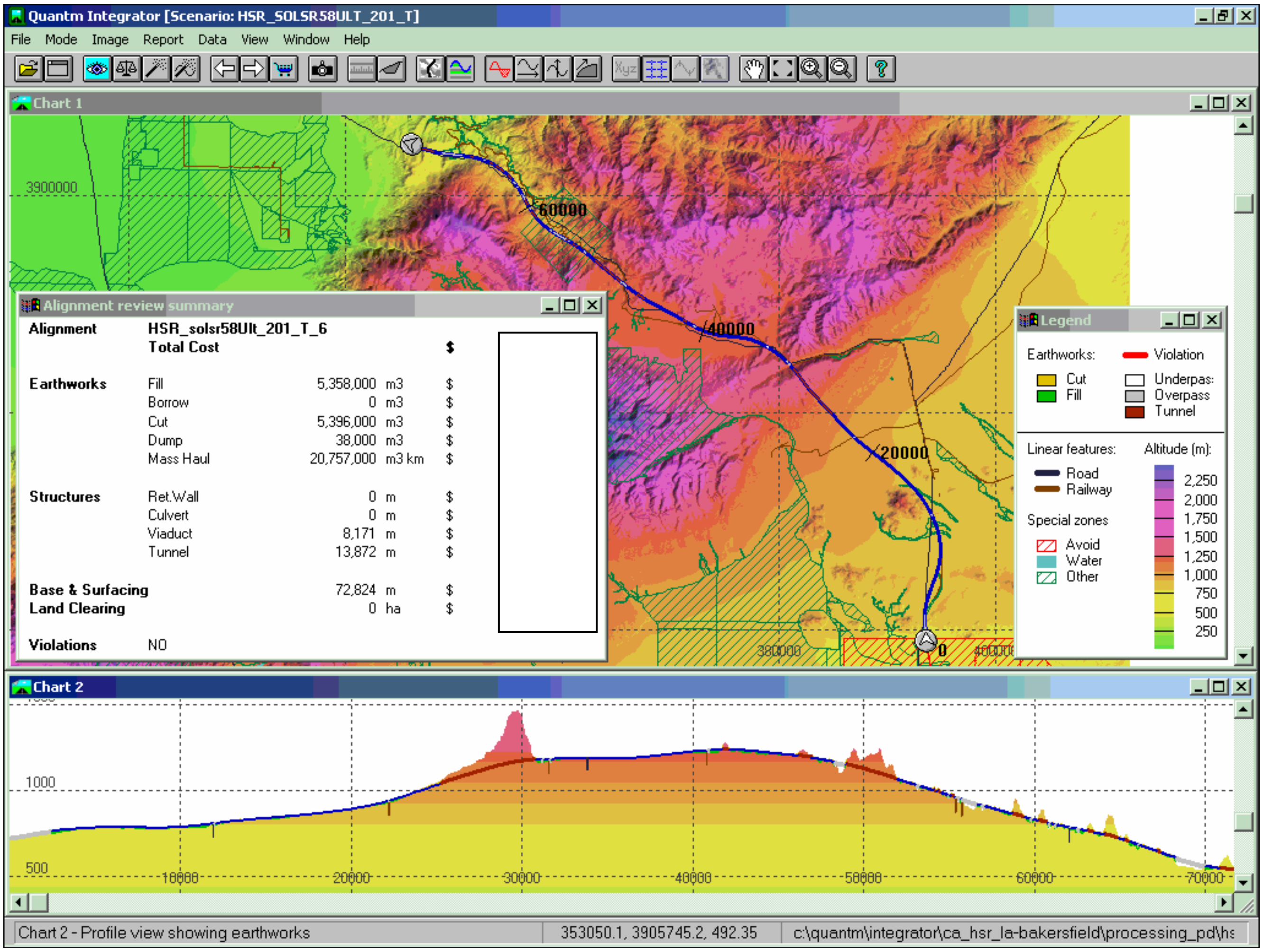

FIGURE 5-38: SR-58 NORTH – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

D. Quantm Derived alignment – Northern section with 40m max. cut & fill (3.5% Max. grade)

The maximum cut and fill height allowed before imposing a structure was increased from 20m to 40m to replicate previous studies undertaken to minimize tunnels. Figure 5-39 shows an alignment option (HSR_SOLSR58Ult_206_T_18) that has reduced the total tunnel length to 5.1 miles and cut the construction cost to $998 million. This represents a $227m or 19% reduction on the alignment that was constrained to 20m cut and fill. Since the previous studies undertaken to minimize tunnels were done using different terrain data, there is no benchmark cost available for this option.

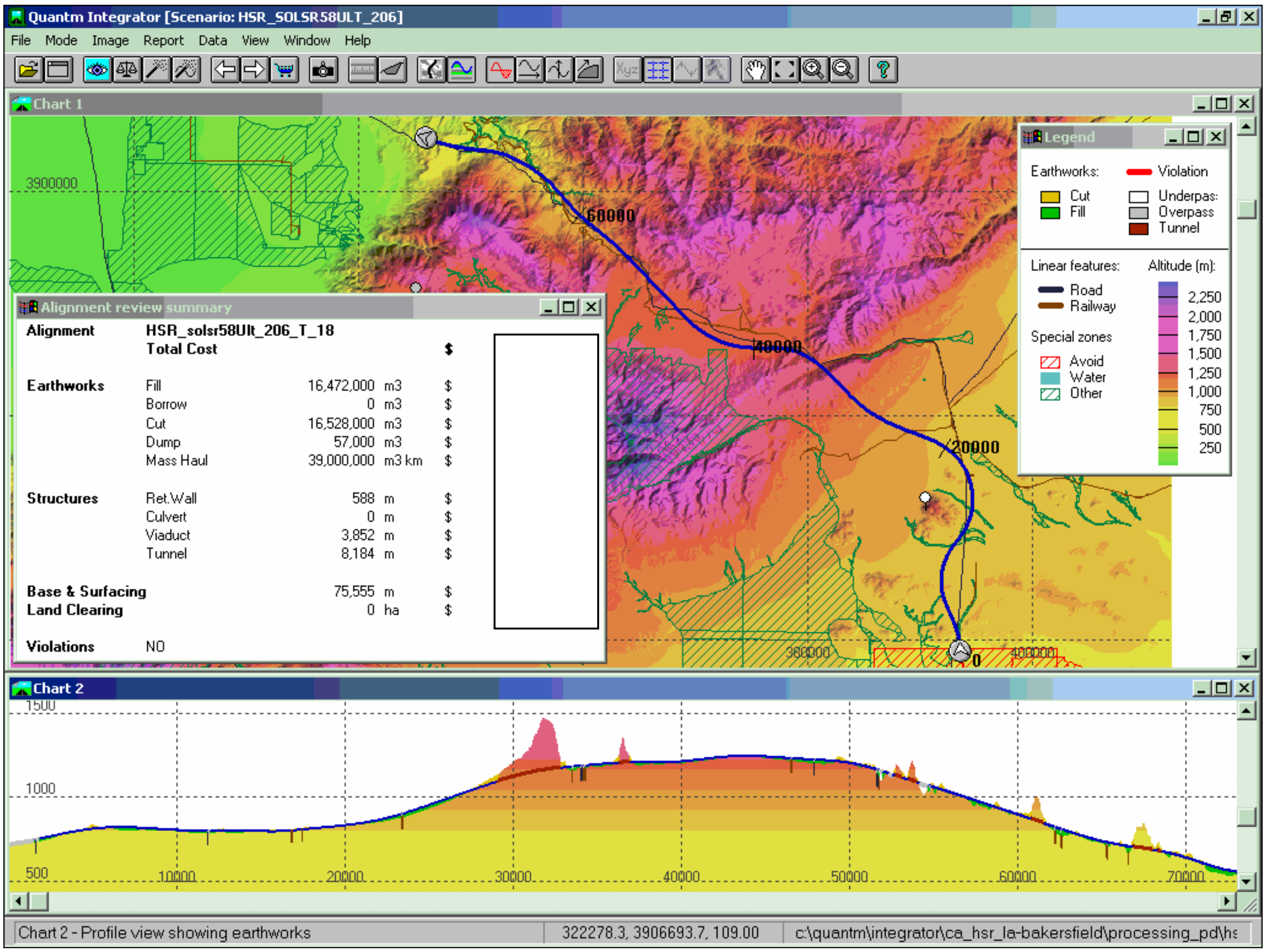

FIGURE 5-39: SR-58 NORTH – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

Figure 5-40 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. SOLSR58_206_18T_17 has an alignment construction cost of $854 million and a maximum single tunnel length of 1.7 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5.0% that reduced tunneling by 29.4% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 15%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

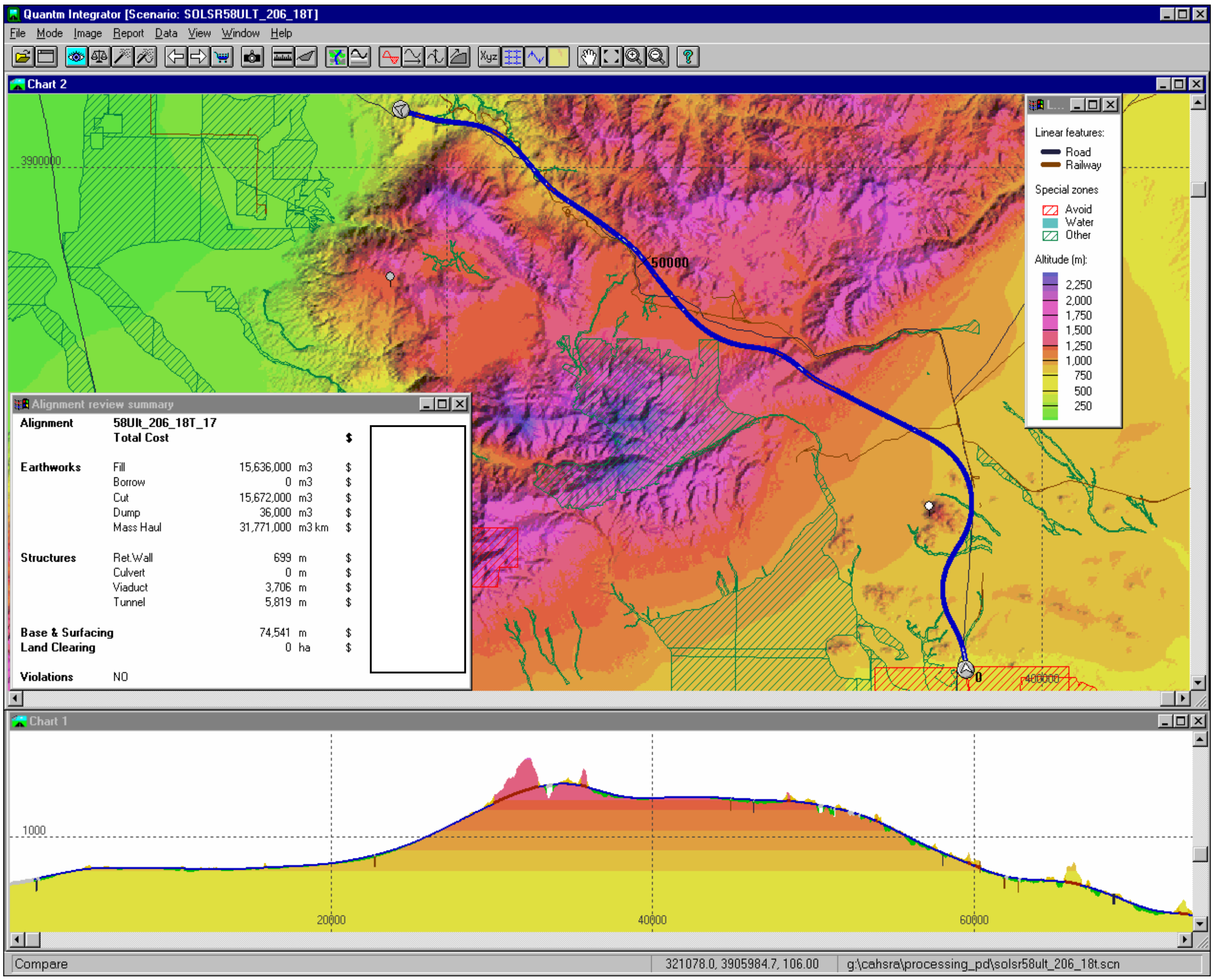

FIGURE 5-40: SR-58 NORTH – QUANTM REFINED ALIGNMENT (MAX. 5.0 % GRADE)

TABLE 5-5: SR-58 / MOJAVE ALIGNMENT COMPARISON SUMMARY

Alignment	Total Length	Total Tunnel Length	Maximum Tunnel Length	Alignment Construction Cost (billions)
Southern Section				
Screening Alignment Option – Soledad Canyon with tunnel (Original South - SR58SEED~SEED)	33.4 miles	21.4 miles	3.1 miles (9.5 miles if meet constraint)	$2.17
Refined Alignment Option Soledad Canyon with tunnel (Quantm - HSR_SOLSR58Ult_03_TI_7)	33.6 miles	15.2 miles	9.1 miles	$1.97
Screening Alignment Option – Soledad Canyon w/out tunnel (Original South - SR58~SEED~SEED~SEED)	33.4 miles	20.4 miles	3.4 miles	$2.10
Refined Alignment Option Soledad Canyon w/out tunnel (Quantm - HSR_SR58Ult_05_TI_11)	33.6 miles	11.1 miles	2.8 miles	$1.32
Screening Alignment Option - SR-14 (Original SR-14 - SR14SR58~SEED~SEED)	33.6 miles	20.0 miles	4.7 miles	$2.14
Refined Alignment Option - SR-14 Max Grade 3.5% (Quantm - HSR_SR14SR58_103_TI_19)	33.6 miles	13.4 miles	2.9 miles	$1.52
Refined Alignment Option - SR-14 Max Grade 3.5% and 40m Max Cut & Fill (Quantm - HSR_SR14SR58_104_TI_1)	33.7 miles	8.5 miles	2.1 miles	$1.26
Refined Alignment Option - SR-14 Max Grade 5.0% and 40m Max Cut & Fill (Quantm - HSR_SR14SR58_104_7T_3)	34.0 miles	6.6 miles	2.6 miles	$1.04
Refined Alignment Option (Alternative) (Quantm - HSR_SOLSR58Ult_03_T_18)	33.4 miles	11.1 miles	2.8 miles	$1.27
Northern Section				
Screening Alignment Option 2.8% Max Grade (Original North~SR58NORTH~SEED~SEED)	46.1 miles	23.6 miles	12 miles	$3.27
Refined Alignment Option 2.8% Max Grade (Quantm - HSR_SR58Ult_205_T_10)	47.6 miles	9.6 miles	3.8 miles	$1.33
Refined Alignment Option 3.5% Max Grade (Quantm – HSR_SR58Ult_201_T_6)	45.2 miles	8.6 miles	3.1 miles	$1.22

TABLE 5-6: SR-58 / MOJAVE ALIGNMENT COMPARISON WITH MAX 40M CUT AND FILL

Alignment	Total Length	Total Tunnel Length	Maximum Tunnel Length	Alignment Construction Cost (billions)
Southern Section				
Refined Alignment Option Soledad Canyon w/out tunnel (Quantm - HSR_SOLSR58Ult_07_T_4)	33.8 miles	5.2 miles	2.2 miles	$0.91
Refined Alignment Option Soledad Canyon w/out tunnel Max Grade 5.0% (Quantm - HSR_SOLSR58Ult_07_4T_13)	33.9 miles	4.9 miles	2.8 miles	$0.84
Corridor Evaluation Alignment Soledad Canyon Option	N/A	5.3 miles	N/A	N/A
Northern Section				
Refined Alignment Option (Quantm – HSR_SOLSR58Ult_206_T_18)	46.9 miles	5.1 miles	2.4 miles	$1.00
Refined Alignment Option Max Grade 5.0% (Quantm – SOLSR58Ult_206_18T_17)	46.3 miles	3.6 miles	1.7 miles	$0.85
Corridor Evaluation Alignment SR-58/Mojave Option	N/A	5.8 miles	N/A	N/A

5.2.3 SR-138 / Palmdale

Given the flat nature and the existing development constraints of the Antelope Valley, the study team elected to ignore the flat section of this route and focus on the mountain crossing. The crossing was tested at maximum grades of 2.5% and 3.5%.

A. Screening Alignment option - SR-138

The screening alignment option for this corridor (Option_SR138~Se~S) is shown in Figure 5-41. This alignment was the result of studies undertaken during the screening evaluation and involved approximately 20-30 days of engineering development time over the last year. This alignment has a maximum single tunnel length of 14.2 miles, which is beyond the desirable maximum tunnel length.

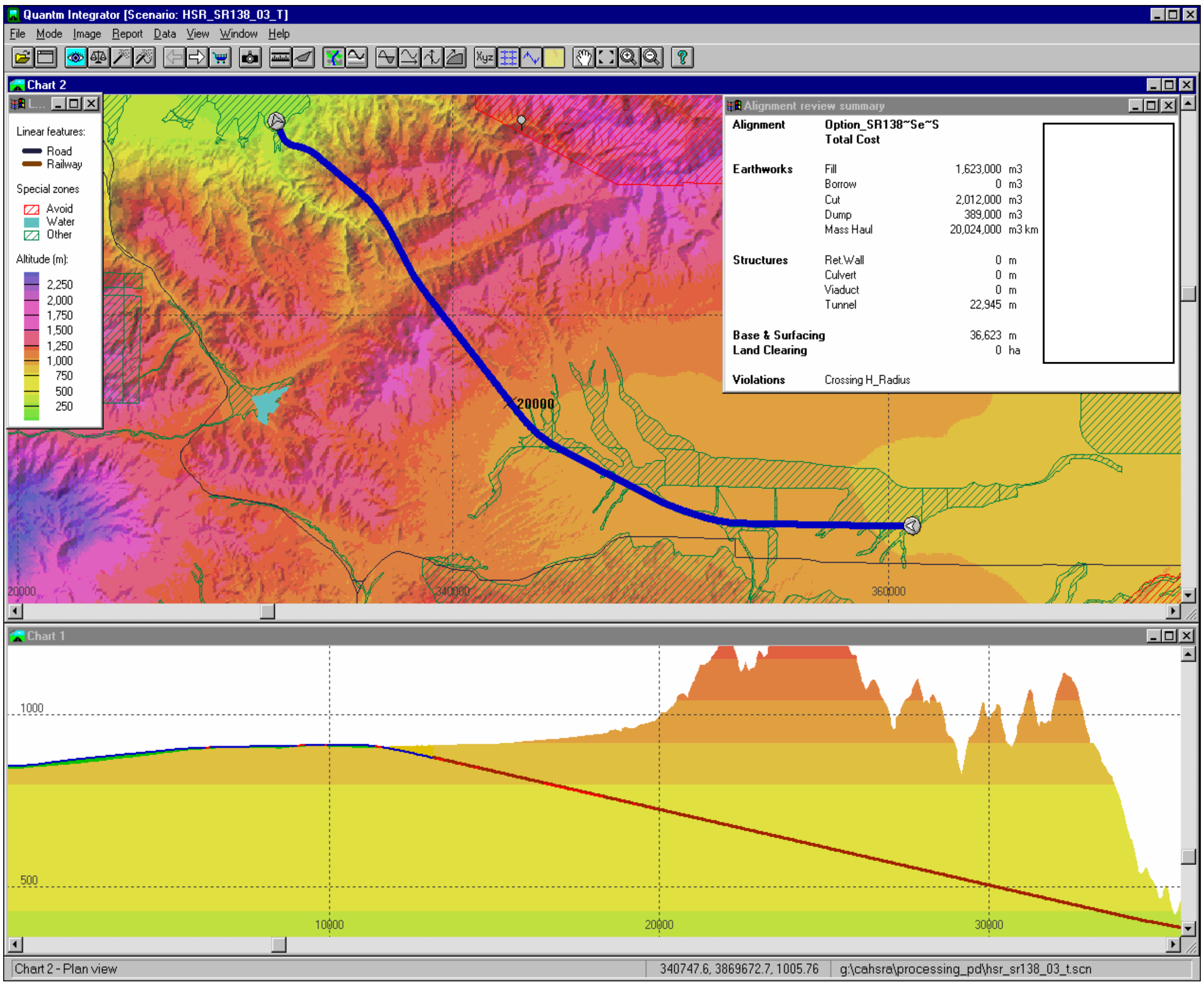

FIGURE 5-41: SR-138 – ORIGINAL ALIGNMENT (MAX. 2.5% GRADE)

B. Quantm Derived alignment options

The study team applied the Quantm system and identified an alignment option (HSR_SR138_03_T_5) that reduces the length of the tunnel by more than 10% to 12.8 miles. This is considered to be the shortest tunnel possible with a 2.5% maximum grade. The Garlock Fault zone is crossed at depth in tunnel on this alignment.

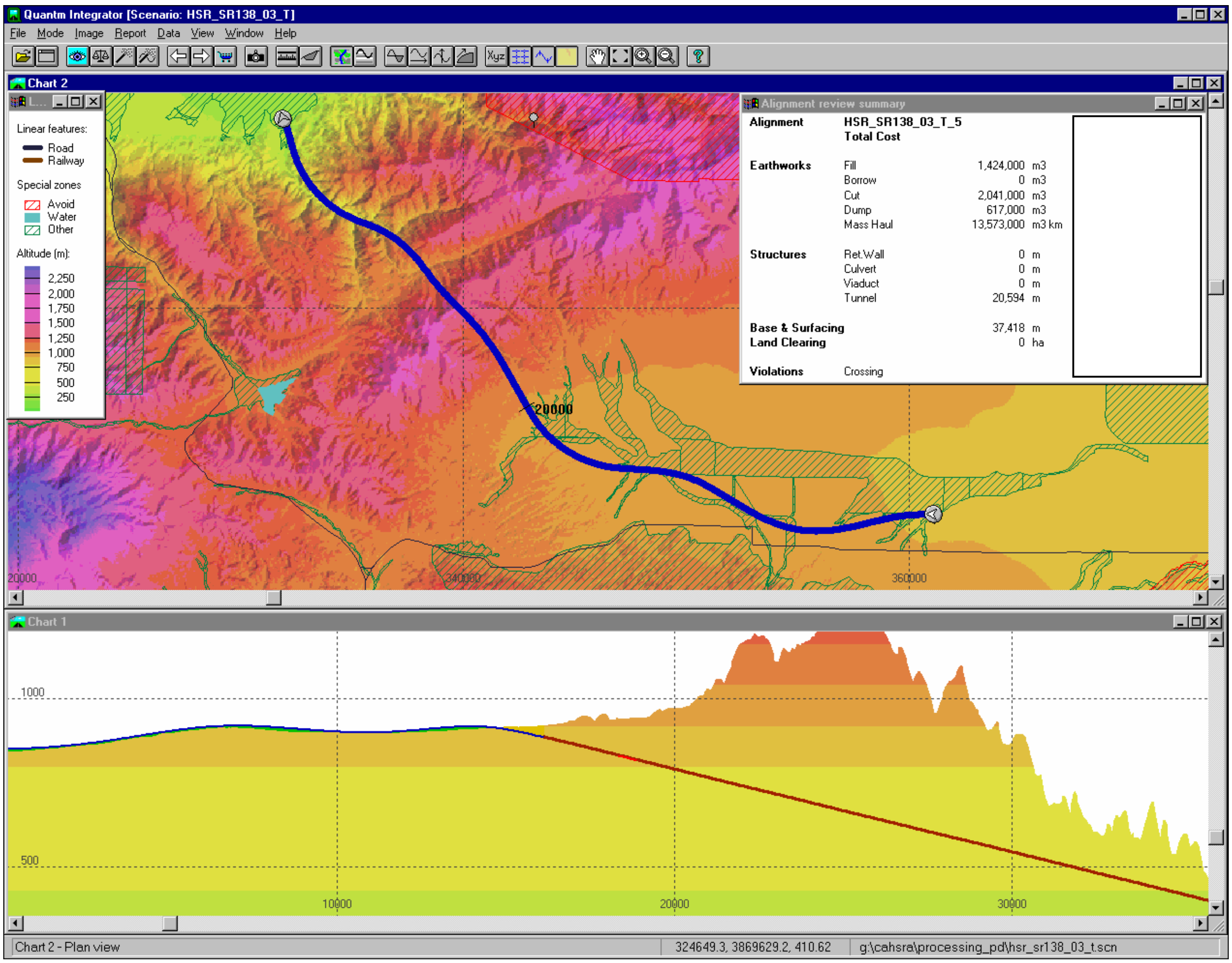

FIGURE 5-42: SR-138 – QUANTM ALIGNMENT (MAX. 2.5% GRADE)

The speed of the Quantm system enabled sensitivity analysis to be quickly undertaken to consider the implications of increasing the maximum grade to 3.5%. This merely required amending the grade in the system and submitting the new scenario for optimization.

Within three hours, the study team was able to review alignment options that indicated the increase in maximum grade could reduce the tunnel length from 12.8 miles to 10.4 miles and the alignment construction cost from \$1.90 billion to \$1.42 billion. Figure 5-43 shows the alignment option (HSR_SR138_04_T_2).

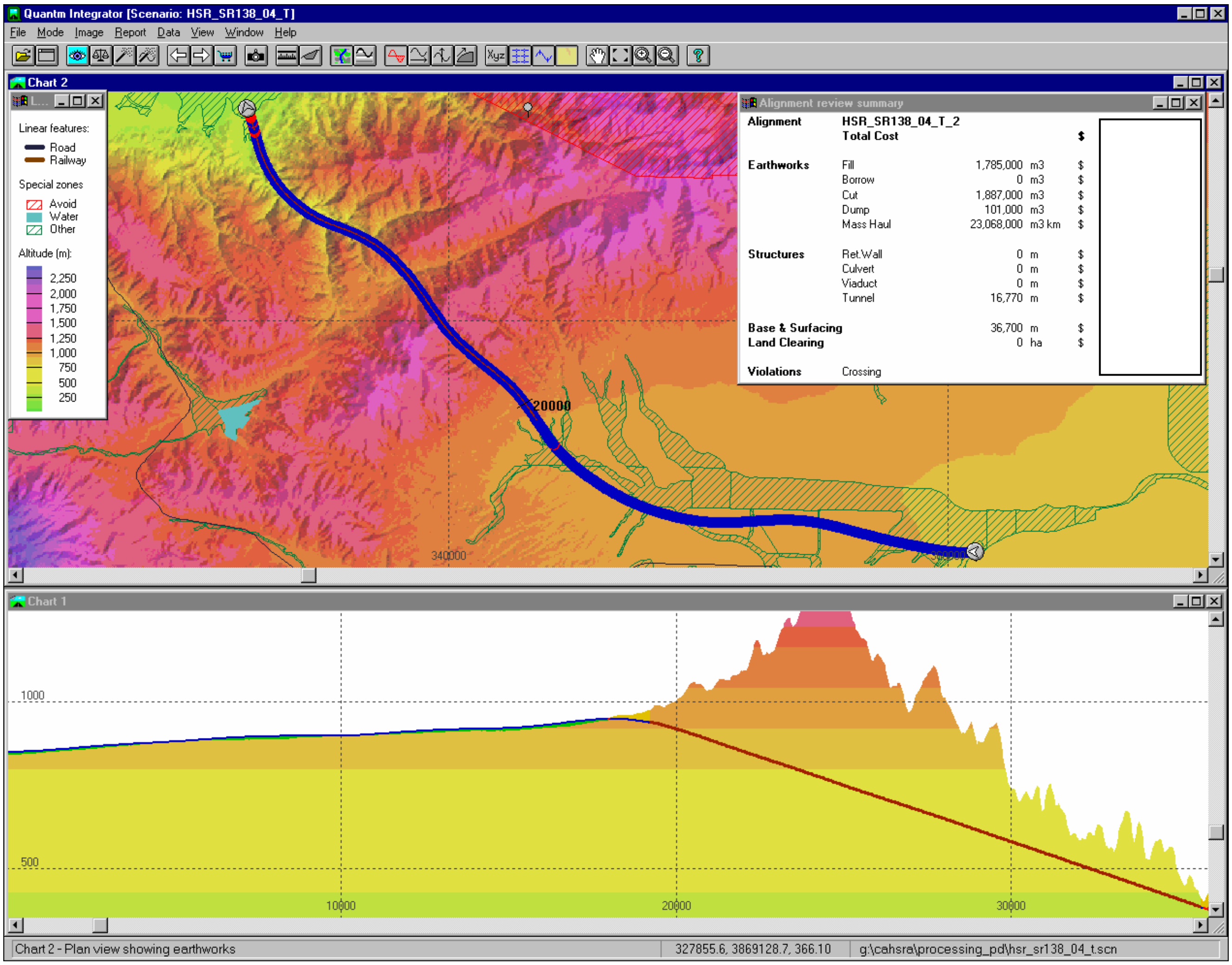

FIGURE 5-43: SR-138 – QUANTM ALIGNMENT AT MAXIMUM GRADE OF 3.5%

Figure 5-44 shows a similar alignment option with 40m max cut & fill grading limits and a maximum gradient of 5.0%. HSR_SR138_04_2T_20 has an alignment construction cost of $1.27 billion and a maximum single tunnel length of 8.8 miles. Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 11.5% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 10.6%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

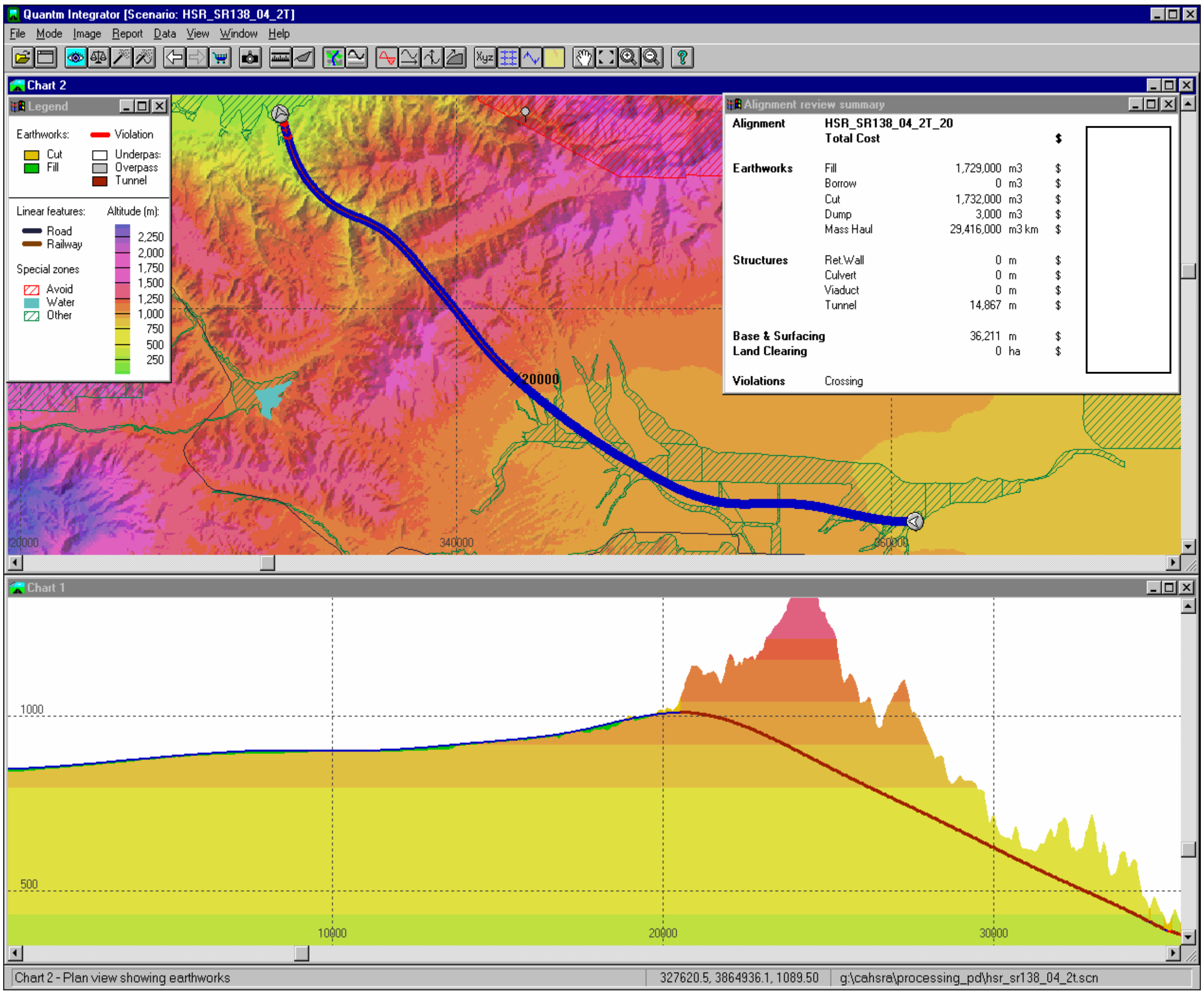

FIGURE 5-44: SR-138 – QUANTM ALIGNMENT AT MAXIMUM GRADE OF 5.0%

TABLE 5-6: SR-138 ALIGNMENT COMPARISON SUMMARY

Alignment	Total Length	Total Tunnel Length	Maximum Tunnel Length	Alignment Construction Cost (billions)
Screening Alignment Option Grade Max 2.8% (Original - Option_SR138~Se~S)	22.7 miles	14.2 miles	14.2 miles	$1.91
Alignment Refinement Grade Max 2.5% (Quantm -HSR_SR138_03_T_5)	23.2 miles	12.8 miles	12.8 miles	$1.90
Alignment Refinement Grade Max Grade 3.5% (Quantm - HSR_SR138_04_T_2)	22.8 miles	10.4 miles	10.4 miles	$1.42
Alignment Refinement Max Grade 5.0% (Quantm - HSR_SR138_04_2T_20)	22.5 miles	9.2 miles	8.8 miles	$1.27

5.2.4 Summary of Quantm Application on Tehachapi Pass

In less than three weeks, the application of the Quantm system enabled the study team to undertake comprehensive assessment of the options between Santa Clarita and Bakersfield, subject to the constraint data currently defined. This three-week study delivered alignments that significantly improved on the amount and cost of required infrastructure on the alignment options that had been developed for the screening evaluation.

The ability to quickly install new constraints to protect sensitive areas or guide the alignments was demonstrated in the investigation of the I-5 corridor where constraint zones were used to minimize the impact of crossing the fault lines. It took minutes to define the zones and new alignments that avoided or minimized impact to the new constraints were returned for review in just two hours. This introduces a new capability in terms of the time and resources required to investigate and assess avoidance alternatives that has not previously been possible on alignment studies and indicates the contribution the system can make during the environmental and public consultation phases.

The system enabled the study team to improve the technical basis for the screening evaluation by analyzing a broader range of potential alignment and profile options and identifying alignment options that significantly reduce tunneling requirements and the associated construction costs. This analysis was completed with the capability to maintain the context of the physical and environmental constraints. The I-5 analysis is an example of this capability, where alignments were identified that indicate potential reductions in alignment costs as much as $2 billion, or 45%, while also reducing the maximum single tunnel length from 14.3 miles to 6 miles and crossing the critical fault zones at-grade.

What this study has demonstrated is that the Quantm system is a support tool that has enabled High-Speed Rail Authority's staff and consultant teams to study an extensive range of options in a considerably short timeframe and will allow the planners to continue to optimize the alignments as new constraints are defined through the consultation and environmental analysis phases, assessing the implications and investigating alternatives.

6.0 CONCLUSIONS

In general, the alignment refinement/optimization study provided additional technical basis for the screening decisions to be made and achieved all of the study objectives to some extent. Many conclusions were reached that are relevant to the screening decisions to be made. Other conclusions were also reached pertaining to the application of the Quantm system to this project and the alignment development process in general.

6.1 ALIGNMENT SCREENING CONCLUSIONS

In the discussion below, the results of the Quantm alignment refinement and optimization study are compared to the alignment options developed during the current alignment screening evaluation as well as alignment options that were developed in the previous Corridor Evaluation Study (1999). There is typically a wide difference in the infrastructure requirements (tunnel and structure length) of the alignment options developed in these two studies, due to the differing objectives of the two studies. It is important to note that the current screening evaluation focused on minimizing potential environmental impacts, while the previous corridor evaluation study focused on minimizing tunnel requirements and cost. Based upon the results of the Tunneling Conference, the Quantm study has attempted to minimize tunneling and capital costs, and therefore is more comparable to the earlier Corridor Evaluation Study results.

6.1.1 Northern Mountain Crossing – Diablo Mountains

A. Diablo Range Direct Alignment (previously Northern Direct Tunnel)

Of the two primary corridors being considered in the Diablo Mountain Crossing, the northern alignment is advantageous in terms of travel time; however, the terrain is more difficult and remote. Because of time and resource constraints, the previous northern alignment studies in the screening evaluation had assumed that the crossing needed to be completely in tunnel because of the difficult and remote terrain. As a result, the only alignment considered included a 31.9-mile long tunnel through the mountain crossing. A tunnel of this length, however, is costly and difficult to construct.

Using the Quantm system the study team was able to identify an alignment at a maximum grade of 3.5% that minimizes tunneling to a total of 11.6 miles and limits single tunnel length to less than 5 miles – reducing the associated construction cost by at least $2.8 billion. Figure 6-1 shows the refined northern crossing alignment and profile. The alignment would cross three active and potentially active faults at-grade including the Ortigalita Fault, the southern extension of the Greenville Fault trend, and the Calaveras Fault zone. The most negative aspects of this alignment are that it bisects a portion of the Henry W. Coe State Park and it is located several miles south of the nearest access road (SR-130).

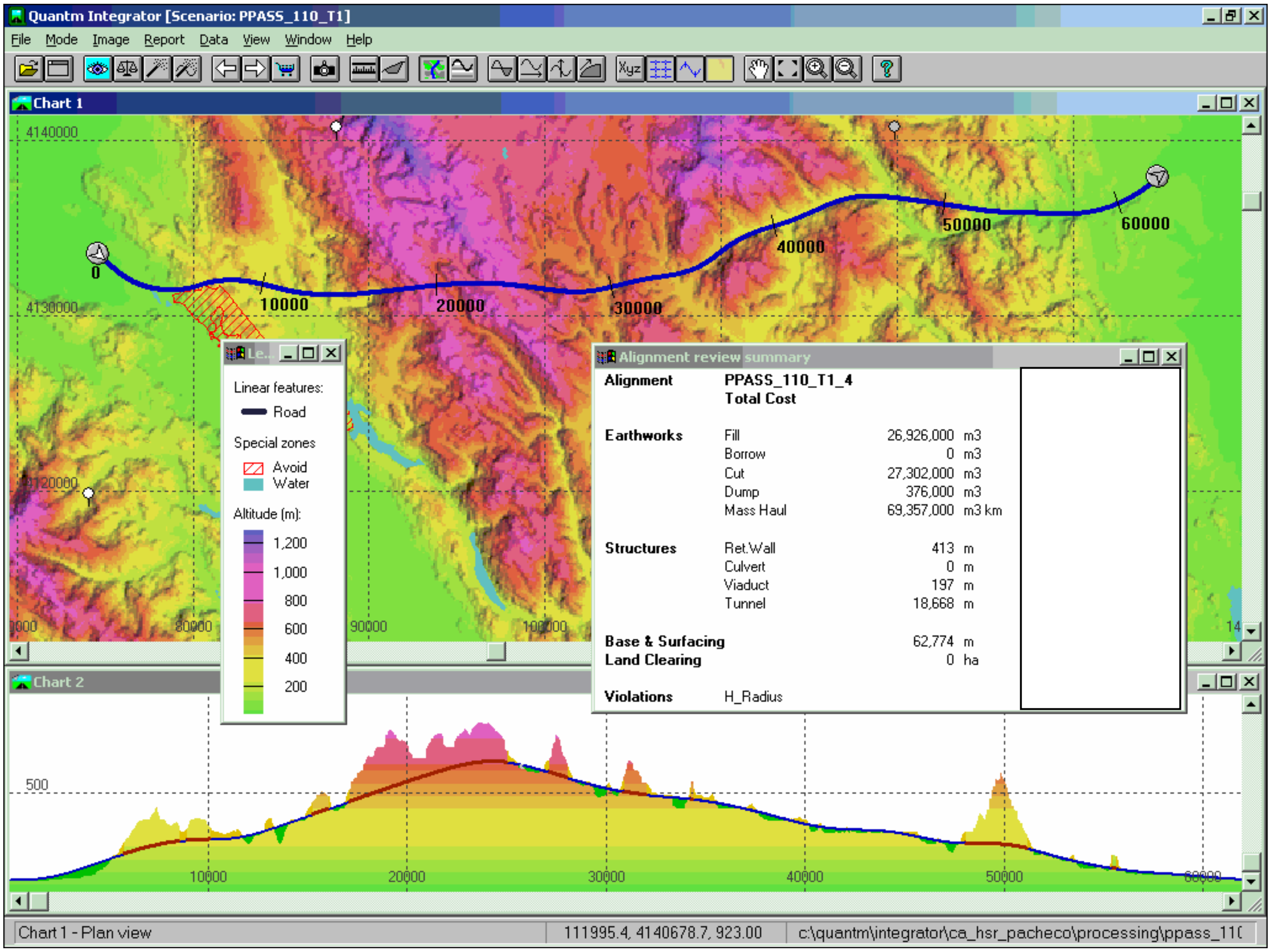

FIGURE 6-1: DIABLO RANGE DIRECT – QUANTM ALIGNMENT AT 3.5% MAXIMUM GRADE

As a possible avoidance alternative to potential impacts to the Henry W. Coe State Park, an additional alignment was developed for the northern crossing that minimizes tunneling (requiring about one-half of the tunneling proposed in the previous direct tunnel option), avoids direct impact to the Henry W. Coe State Park (a key environmental constraint) and is located in close proximity to SR-130 to provide construction access. This avoidance alignment option has a total tunnel length of 16.1 miles and a maximum length of continuous tunnel of 5 miles.

Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 18.1-31.1% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 2.9-12.2%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades.

B. SR-152 – Pacheco Pass

The previous alignment option considered in the screening evaluation required a total length of 18 miles of tunnel with a maximum length of continuous tunnel of 15 miles. The alignment option identified in the previous Corridor Evaluation Study (1999) required 12 miles of tunnel with a maximum segment length of 4.5 miles. Refinement of this SR-152/Pacheco Pass alignment at 3.5% max grade identified an alignment and profile option that can potentially reduce the total required tunneling to only 5.2 miles. Figure 6-2 shows the refined SR-152/Pacheco Pass alignment option.

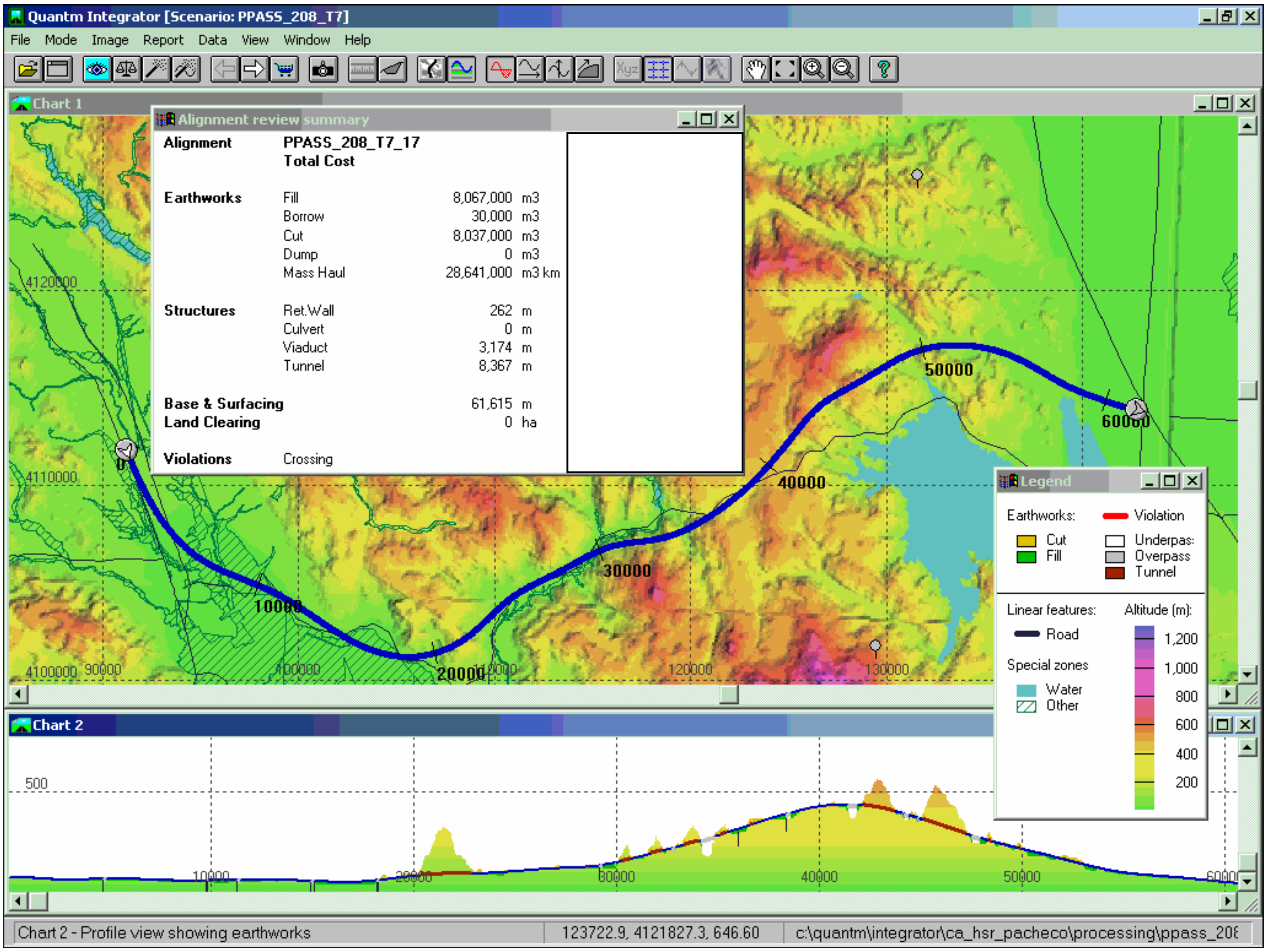

FIGURE 6-2: PACHECO PASS – QUANTM SR-152 ALIGNMENT (MAX. 3.5% GRADE)

Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 11.5% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 8.2%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades

6.1.2 Southern Mountain Crossing - Tehachapi Mountains

In the Tehachapi Mountain Crossing the alignment refinement/optimization study confirmed the location of the general corridors considered in the screening studies to date. A. I-5/Grapevine
The alignment refinement/optimization study confirmed past findings as well as identified new alignment options in key seismically constrained areas.

Alignment options using 2.5% maximum grades are unable to cross major faults at grade and require a continuous tunnel segment of at least 14.7 miles. However, alignment options using 3.5% maximum grades were found to provide more flexibility in avoiding the major faults at-grade than previously thought. The alignment options in the I-5 corridor were refined to identify more viable options in the area of the major fault crossings in terms of tunnel requirements, construction difficulty and cost. An alignment was identified to the east of I-5 that allows for an at-grade crossing of the San Andreas Fault zone and an at-grade or trenched crossing of the Garlock Fault zone with no single tunnel longer than 6 miles. This alignment option, as shown in Figure 6-3, would require a total of 17.7 miles of tunneling as compared to 28 – 35 miles of tunneling required for alignment options previously studied. This alignment would require extensive construction in the floodplain area surrounding Castac Lake. The potential impacts will need to be further studied in the program environmental analysis.

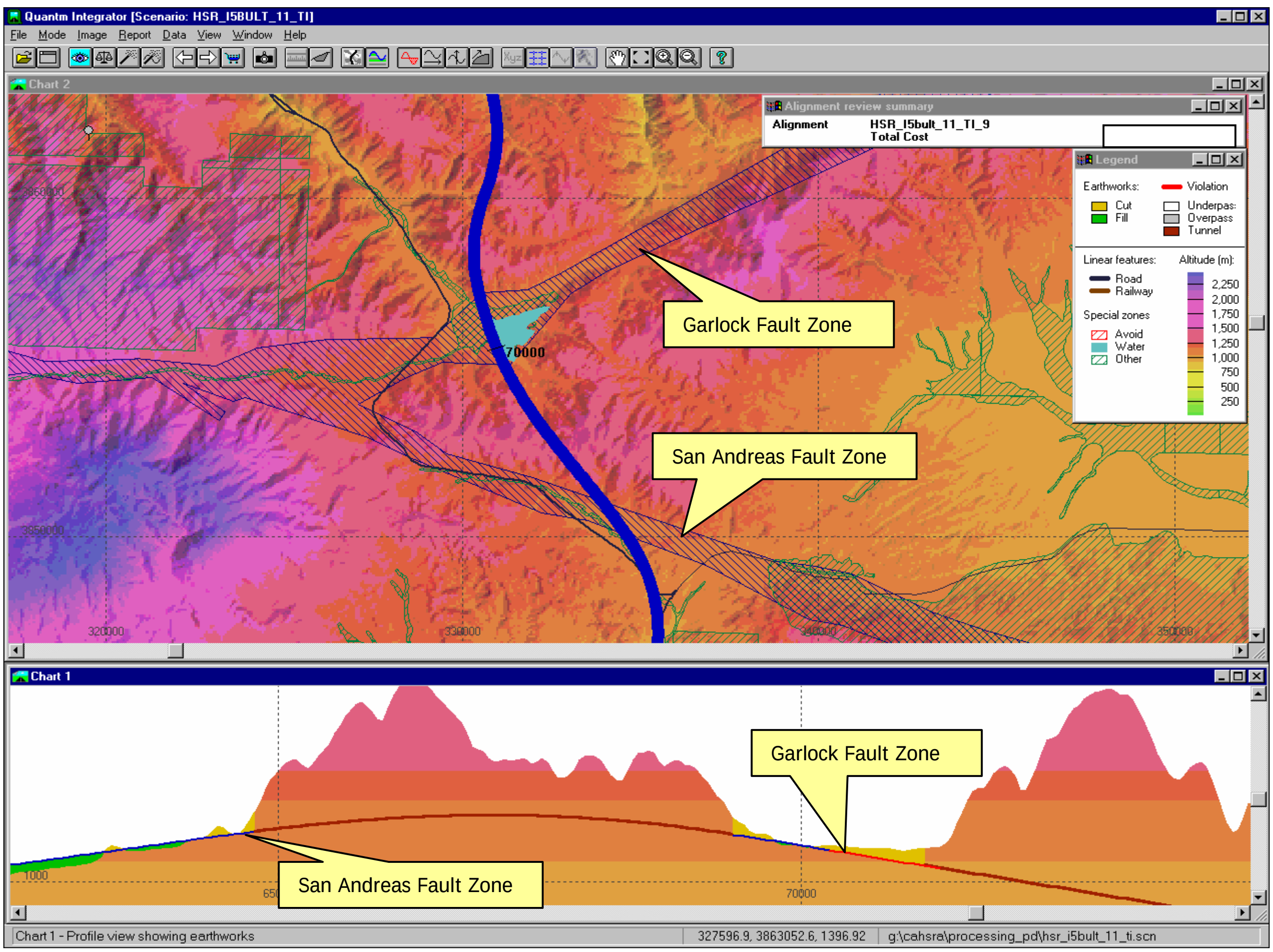

FIGURE 6-3: I-5 QUANTM ALIGNMENT TO EAST OF I-5 CORRIDOR, CROSSING FAULT LINES AT GRADE

Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 24.3-38.9% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 9.9-32.1%. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades

B. SR-58 / Mojave

This corridor was investigated in sections: the southern section from Sylmar to Palmdale, the middle section through Palmdale and Lancaster, and the northern section from Lancaster to the Central Valley floor. The middle section is highly constrained due to existing development and transportation corridors. The northern and southern sections were studied more extensively because of the potential for alignment refinement in the mountainous terrain.

Southern Section (Sylmar to Palmdale) - Two corridor alternatives were studied in the southern section, the SR-14 corridor and the Soledad Canyon corridor. The alignment options in these corridors were refined to identify more viable options or reductions in infrastructure requirements and cost. The Soledad Canyon alignment option developed in the screening assumed tunneling along the north side of Soledad Canyon to avoid potential environmental impacts. By eliminating that constraint and taking a more aggressive approach to earthworks, tunneling can be reduced by as much as 16 miles as compared to the alignment option developed in the screening evaluation. The Quantm alignment option was very similar to that developed in the previous corridor evaluation in terms of required tunneling (5 miles total).

Based on that reduction, the Soledad Canyon alignment option allowed for lesser infrastructure requirements (over 3 miles less tunnel) and cost than the refined SR-14 alignment option. Figure 6-4 shows the Soledad Canyon alignment option. Figure 6-5 shows the refined SR-14 alignment option.

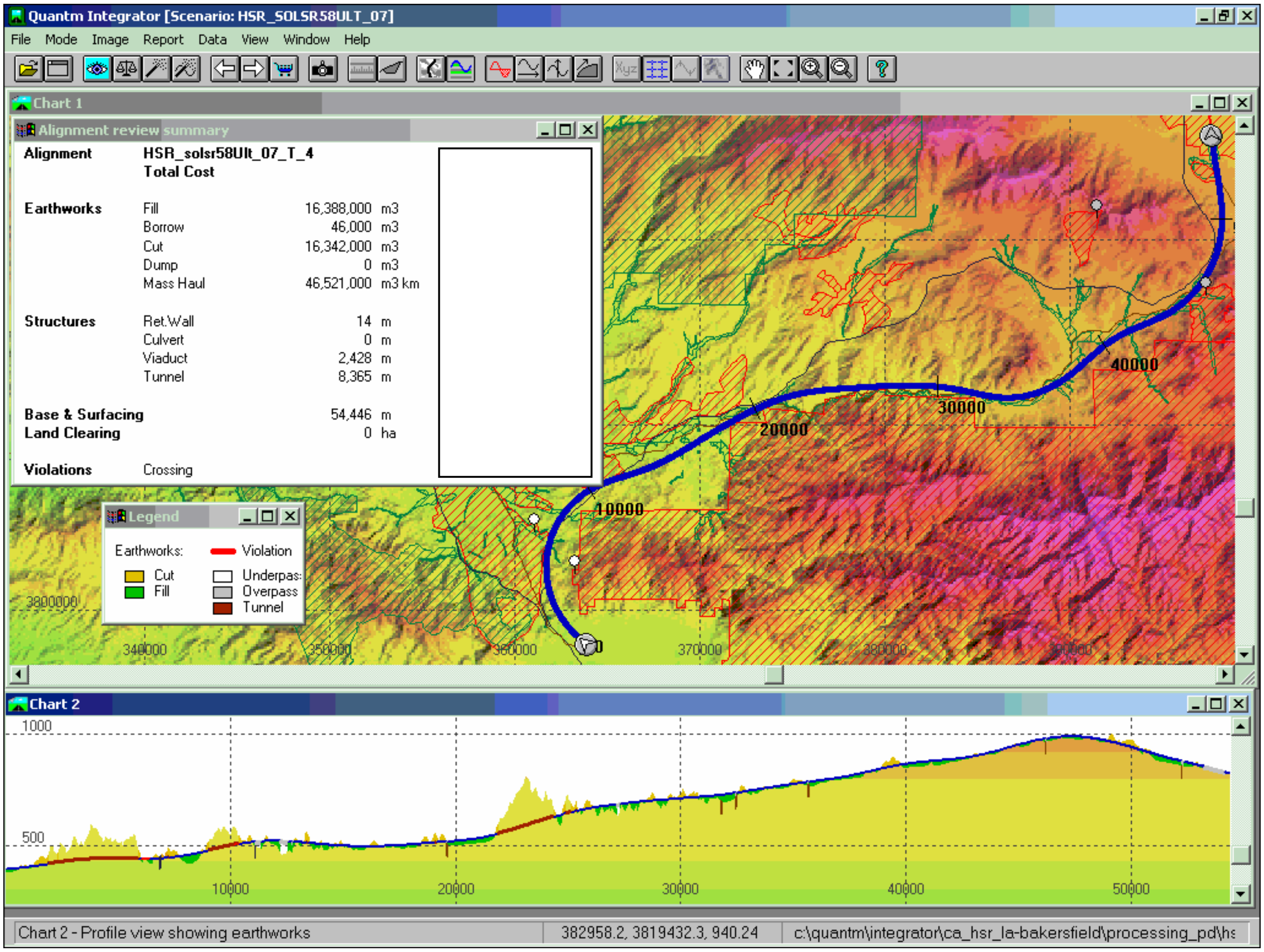

FIGURE 6-4: SOLEDAD CANYON – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

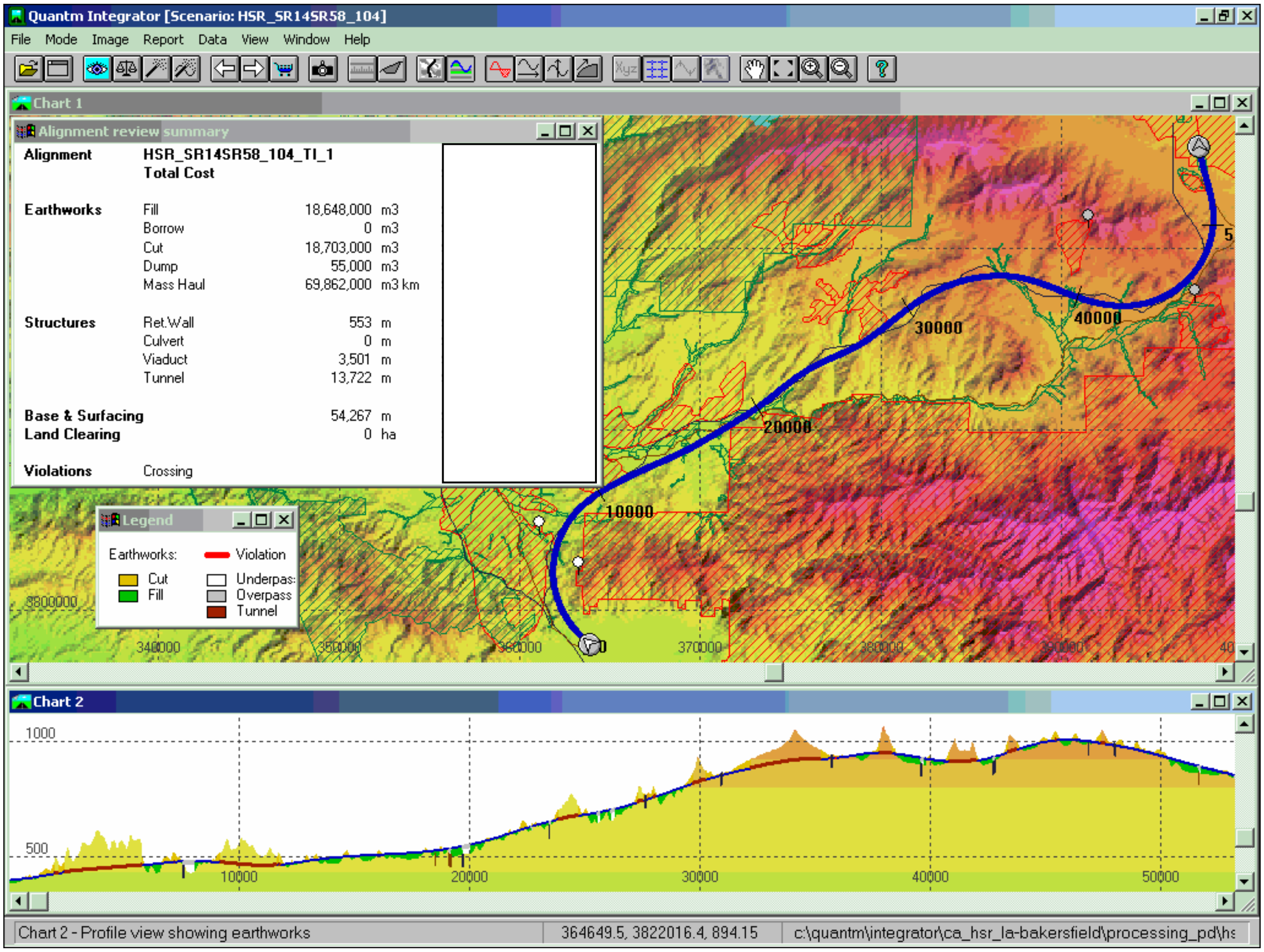

FIGURE 6-5: SR-14 – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 5.8-22.4% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 7.7-17.5%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades

To avoid the potentially sensitive areas of Soledad Canyon, an avoidance alignment option was identified to the north of Soledad Canyon that would still reduce tunneling requirements as compared to the Soledad Canyon alignment option previously considered in the screening analysis. Potential environmental impacts of this alignment option will be further evaluated in the program environmental studies.

Northern Section (Lancaster to Central Valley) - The alignment options in the SR-58 corridor were refined to identify more viable options or reductions in infrastructure requirements and cost. No new, significantly different corridor options were identified. The minimum length of tunneling required through the Tehachapi Mountain crossing on the SR-58 corridor at a max grade of 3.5% is 5.1 miles as compared to 24 miles for the alignment options considered in the screening evaluation (at 2.8% maximum grade) and 5.8 miles for the alignment option considered in the previous corridor evaluation. Figure 6-6 shows the refined alignment option. All major fault crossings can be maintained at-grade for the 3.5% maximum grade option in this corridor.

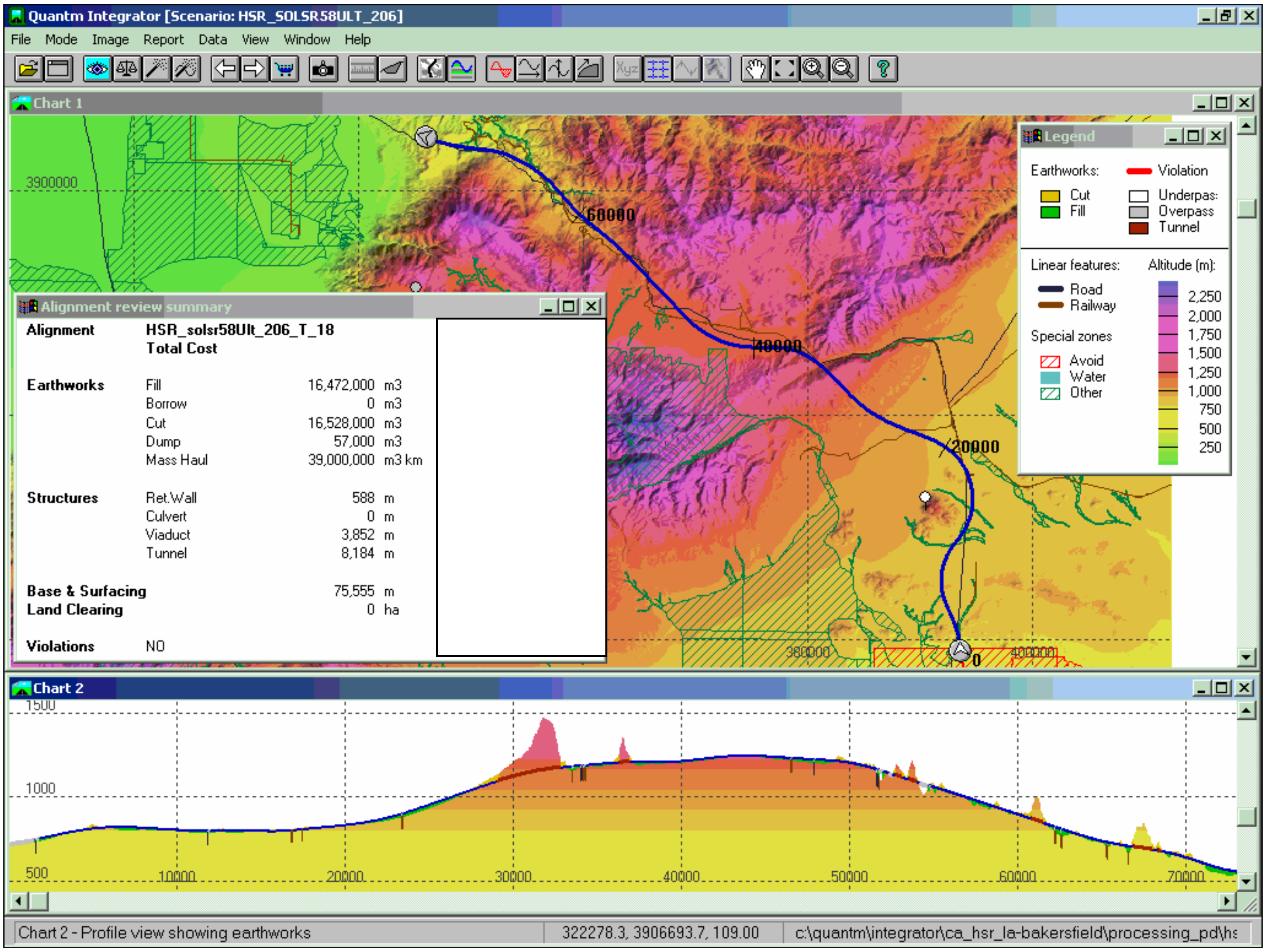

FIGURE 6-6: SR-58 NORTH – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 29.4% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 15.0%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades

C. SR-138/Palmdale Alignment

The southern section of this alignment is the same as the SR-58/Mojave alignment option discussed above.

The alignment and profile options through the Tehachapi Mountain Crossing were refined to identify more viable options that reduce infrastructure requirements and cost. A single tunnel segment is required for this crossing and was estimated at 14.2 miles long in the screening evaluation. The length of tunnel required on this crossing can be reduced as low as 12.8 miles at 2.5% maximum grade, 10.4 miles at 3.5% maximum grade and 8.8 miles at 5.0% maximum grade. Figure 6-7 shows the refined alignment option at 3.5% maximum grade. No new, significantly different corridor options were identified.

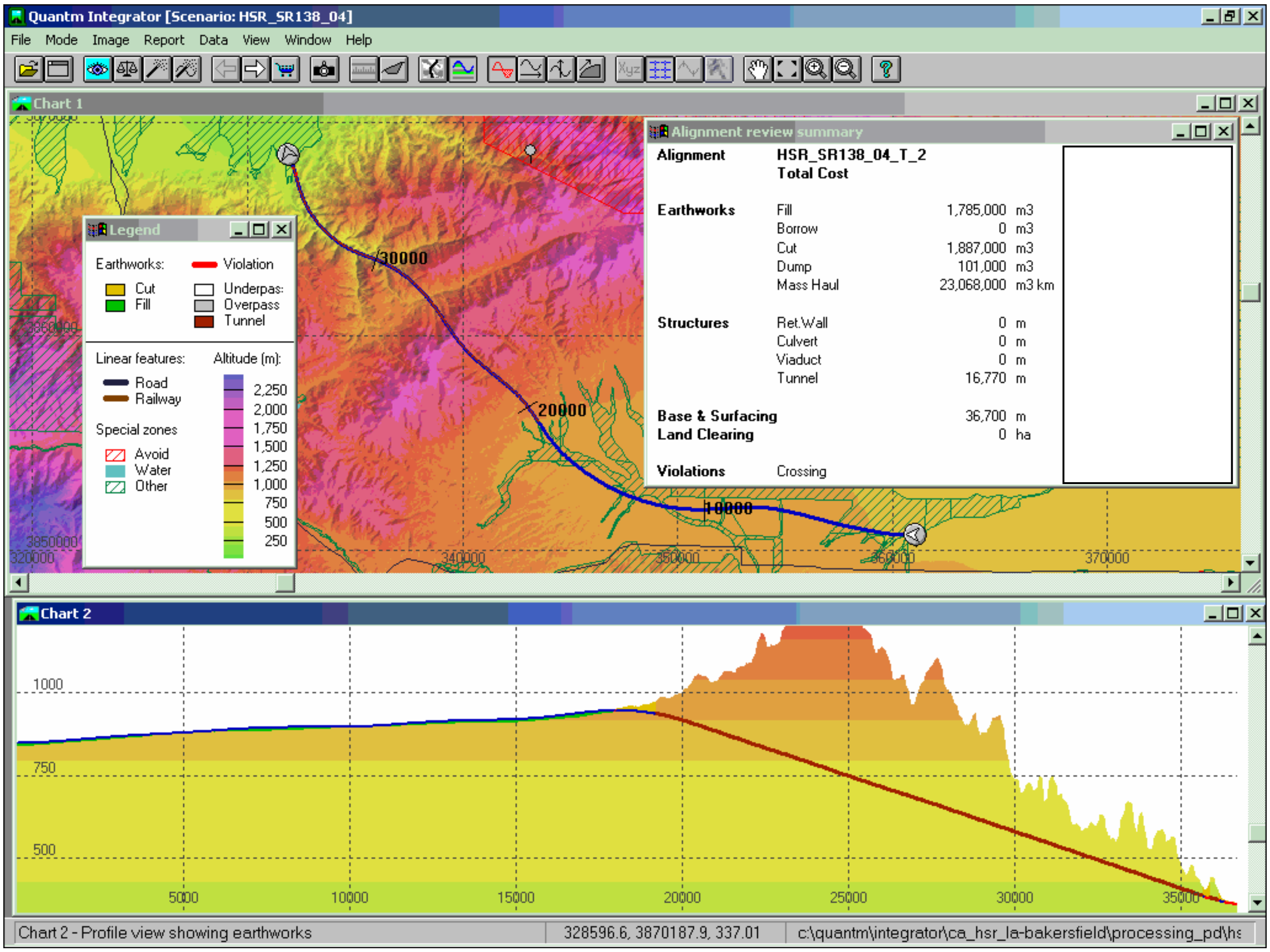

FIGURE 6-7: SR-138 – QUANTM REFINED ALIGNMENT (MAX. 3.5% GRADE)

Using the Quantm system the study team was able to identify alignments in this corridor with maximum grades of 5% that reduced tunneling by 11.5% as compared to the alignment options with 3.5% maximum grade. The associated alignment costs for these alignments reduced by 10.6%. The reduction in alignment cost is not as significant as the reduction in tunneling length, due to increased requirements for bridges and earthwork on the alignments with 5% maximum grades. It is important that while these alignments were derived in the same general corridor, the optimal alignments using 5% maximum grades are different than the alignments identified using 3.5% maximum grades

6.2 RESULTS OF QUANTM EVALUATION

The study team and Authority staff concurred that the primary benefit of the Quantm system and this alignment refinement/optimization study was the confidence gained that the optimal alignment options are being considered in terms of minimizing infrastructure requirements and costs for both of the mountain crossings studied. The Authority would not have had the time or resources to identify and evaluate the broad range of potential options/variations (literally millions) through these mountain crossings and achieve this level of confidence through any other means.

This three-week study identified alignment options and refinements that significantly improved on the original alignments that had been developed in previous studies. The Quantm system was particularly applicable to the screening evaluation process. The ability to quickly test a wide range of alignment options in the context of all of the key environmental and physical constraints, as well as the main design and cost parameters was critical to achieving the objectives of this study. It became apparent that the earlier this type of comprehensive evaluation is conducted in a corridor/alignment study, the more effective the outcomes. This is particularly true in terms of providing early, accurate indications of alignment options and associated cost and potential impacts.

The ability to input new constraints to protect sensitive areas or avoid physical features was demonstrated in the investigation of the I-5 corridor where constraint zones were used to minimize the impact of crossing the fault zones, based on input from the tunneling conference. While these concerns can certainly be addressed through conventional study means, the Quantm system provided a comprehensive plan, profile and costing analysis in a very short period of time.

The study team confirmed that it was able to use the Quantm system as a powerful support tool to analyze a wide range of alignment options and identify beneficial refinements in a remarkably short time with more flexibility to respond to specific engineering and environmental issues. The study team also confirmed that the Quantm system would be applicable to subsequent stages of the alignment development process to optimize the alignments as new constraints are defined through the further consultation and environmental analysis phases.

The study team found that the Quantm system had many specific benefits in its application to the current alignment screening stage of project development. The benefits are listed below as well as any limitations that were found. We have also listed potential applications for Quantm system in the subsequent stages of project development for the high-speed train system in California.

6.2.1 Benefits

- Applicability to screening stage of project development because of its capability to analyze a wide range of alignment options in a very short time period.
- Elimination of the need for extensive engineering studies to “optimize earthworks” for each alignment option considered. This allows for a greater range of options to be considered in early stages of alignment development and allows for a more focused approach to the latter stages.
- A reduction in the time and resources required to produce comprehensive results. Once contextual project information is entered, many tests and evaluations can be preformed in just hours.
- Capability to identify alignment options that minimize infrastructure requirements and cost within the context of specified design parameters and all of the known constraints. The capability to address

these engineering issues while simultaneously addressing the environmental concerns in an automated process was very effective.

- Flexibility to address various specific constraints or sensitivity tests in very short time frame. These tests can be focused on a specific parameter or constraint in a specific geologic area or applied throughout an entire corridor.
- Rapid production of plan and profile graphics (on-screen) and quantities with accurate information on infrastructure required and associated costs.
- User Friendly and intuitively easy to use software interface.

6.2.2 Limitations

- Plotting and report capabilities are limited. Screen prints are currently the only means of reporting alignment maps, profiles and other information. Expanded plotting capabilities are required for extensive review of alignment plans and profiles. Also, more effective/flexible graphics capabilities are needed to produce report size graphics. The Quantm integrator software needs to be developed further in this area.
- The software does not allow enough flexibility in an alignment stationing. There is a need to allow for a beginning station other than 0+00, as well as station equations.
- The software needs more flexibility in reporting with Imperial and/or Metric units.
- The software needs more flexibility in viewing results: compare feature needs to allow for profiles comparisons and perhaps the capability to identify differences graphically.
- Modifying special zones and other constraint information can be tedious and time consuming, due to the limitations of the available text editor. Incorporation of an expanded capability text editor would be useful.
- The software produces a 3D spline (polyline) alignment. It would be very helpful to improve the interface/integration with Integraph/InRoads to automate the geometric conversion process.
- Not necessarily a limitation, but more an inconvenience, was the methodology and time to convert the GIS data to Quantm Integrator format. Although it is understood GIS data had been used as a data source on previous projects, this particular project and possibly others in the United States had a very strong emphasis on GIS data and, due to the size of the study, this was quite a time consuming exercise taking approximately 30 hours across the two studies. (Note: Quantm has recently been in contact with some of the technical staff at ESRI, the developers of the most widely used GIS system ArcView, and propose to improve this data conversion/input process. In fact, Quantm has already improved some of their data conversion tools to accommodate the large number of constraints anticipated on United States projects.)

6.2.3 Future Applications

- It is anticipated that the Quantm system will be a useful tool in the further development of the alignments being considered. As new constraints are identified during the environmental studies, Quantm could be applied to identify avoidance and /or mitigation alignment options without extensive time or labor resource requirements. Also, as the selected alignments are refined in the preliminary engineering stages, the Quantm system could be applied to refine and optimize earthworks and other infrastructure requirements.
- Further improve GIS data conversion process – refer Section 6.2.2 above.
- The relationship between the Quantm System and Rail Operations models, such as the statewide model applied in this study, should be evaluated to identify potential integration of the models and/or

results. The capability to consider operational constraints, benefits and costs of particular alignments would be very beneficial at the early stages of alignment screening, as well as later in the preliminary engineering process. In this regard, Quantm had early stage discussions with PB Transit & Rail Systems Inc. (PBTRS) who will be conducting the operational/scheduling studies for the Authority's program. It will most likely be possible to output the Quantm alignments to PBTRS (via a CADD system) so that alignment selections can be sensitized to operational efficiencies. In this way, alignments could be optimized from an infrastructure and cost perspective as well as from an operational point of view.

7.0 REFERENCES

Parsons Brinckerhoff. *Alignment/Station Screening Evaluation Methodology Report (Task 1.5.2),* Prepared for California High-Speed Rail Authority, December 1999.

P&D Environmental, *High-Speed Train Alignment/Station Screening Evaluation, Los Angeles to Bakersfield Region*, Prepared for California High-Speed Rail Authority, July 2001.

Parsons Transportation Group, *High-Speed Train Alignment/Station Screening Evaluation, Merced to Bay Area Region*, Prepared for California High-Speed Rail Authority, July 2001.

Parsons Brinckerhoff. *California High-Speed Rail Corridor Evaluation.* Prepared for California High-Speed Rail Authority, December 1999.

Quantm Integrator: Optimising Transport Route Alignments – User Manual

APPENDICES

APPENDIX – A
Scenario Summaries

Scenario Summaries

NORTHERN MOUNTAIN CROSSING – DIABLO MOUNTAINS

Northern Alignment *(Refinement)*

Scenario Name and Description	Objective of Scenario	Outcome
PPASS_101 ♦ Geotype, Geometric and Cost Inputs defined as per LA - Bakersfield project. ♦ No Linear Feature or Special Zone constraints yet defined.	Initial optimization run with maximum geometric constraints. Determine corridor options to minimize costs of structures and earthworks for the direct tunnel route.	Wrong Guide Points were associated with Start/Finish points. Ignore results.
PPASS_102 ♦ Revised Network file to correct Guide Points to correct Start & Finish Points. Changed Profile Stiffness from 0.8 to 0.9 to improve vertical geometry as per LA - Bakersfield runs.	Rerun initial optimization and test impact of 0.9 stiffness value.	
PPASS_103 ♦ Changed Profile Stiffness from 0.9 to 0.95 to improve vertical geometry as per LA - Bakersfield runs.	Test impact of various 0.95 stiffness value.	
PPASS_104 ♦ Linear Feature and Special Zone constraints as at 10/12/01 added.	Determine effect of some initial constraints on alignments and corridor options.	
PPASS_105 ♦ Maximum Grades revised to 2.5%.	Determine viability of crossing the range at flatter grade.	
PPASS_106 ♦ Start and Finish Points switch for east to west screen presentation. ♦ Added Special Zone "Henry W. Coe State Park as Tunnel zone and removed Avoid zones "Endangered" (for now). MaxCutFill set to 25m. ♦ Revised Geotype file to new unit costs.	Try to fix on constraints, geometric parameters and unit costs.	
PPASS_107 As per PPASS_106: ♦ Added Special Zones "Floodplains and Farms" ♦ Revised all Road Linear Features to correct projection ♦ Max. grades 3.5%	Determine effect of floodplains and revised road constraints. Testing sensitivity between 3.5% Max. grades (PPass_107) and 2.5% Max. grades (PPass_108)	Seed alignment does not match the Start & Finish Points of the network file. Refinement not possible. Review scenario.
PPASS_108 As per PPASS_106: ♦ Max. grades 2.5%	2.5% Max. grades	
PPASS_109	As per PPASS_107.	

Scenario Name and Description	Objective of Scenario	Outcome
As per PPASS_107: ♦ Max. 3.5% grades ♦ "Options_seeds2.a3d" was wrong. Revised the sequential order of the x,y,z points and created a new "Options_seeds3.a3d".		
PPASS_110 As per PPASS_04 except: ♦ Network file changed to PPASS_106 (swapped Start/Finish points).	Total Refinement of Alignment 1 Seed to reproduce PPASS_104_T1.a3d results.	
PPASS_111 As per PPASS_110: ♦ Geotype file changed to PPASS_06 for revised unit rates.	Total Refinement of Alignment 1 Seed to reproduce PPASS_110_T1.a3d results with new unit rates.	
PPASS_112 As per PPASS_111: ♦ Cost file revised to new Tunnel rate.	Total Refinement of Alignment 1 Seed to determine the effect of new Tunnel rate.	
PPASS_113 As per PPASS_109: • Special Zone file PPASS_06Q retained with Henry W. Coe Park Tunnel. ♦ Cost file revised to new Tunnel rate.	Total Refinement of Alignment 1 Seed to determine the effect of new Tunnel rate.	
PPASS_114 As per PPASS_113: • Geotype file PPASS_06 retained with new unit rates. • Special Zone file revised to PPASS_14 with Henry W. Coe Park Ignored. • Cost file revised to PPASS_01.csa with original Tunnel rate. ♦ Network file changed to PPASS_114 for 5% Max grades.	Total Refinement of Alignment 1 Seed to determine 5% Max. Alignments.	
PPASS_115 As per PPASS_114: • Geotype file PPASS_06 retained with new unit rates. • Special Zone file PPASS_06Q retained with Henry W. Coe Park Tunnel. • Cost file revised to PPASS_01.csa with original Tunnel rate. • Network file PPASS_114 retained with 5% Max grades.	Total Refinement of Alignment 1 Seed to determine 5% Max. Alignments.	

Alternative Northern Alignment - closer to State Route (SR) 130 *(Optimization)*

Scenario Name and Description	Objective of Scenario	Outcome
PPASS_301 ♦ Start and Finish Points switch for better screen presentation. ♦ Added Special Zone "Henry W. Coe State Park as Tunnel zone and removed Avoid zones "Endangered" (for now). MaxCutFill set to 25m. ♦ Revised Geotype file to new units costs. Max. 3.5% grades.	Determine effect of some further constraints on alignments and corridor options.	NoGo zone created to the north of the study area to ensure all alignments were kept within the boundaries of the existing DTM.
PPASS_302 As per PPASS_301: ♦ Kept Max. 3.5% grades. ♦ Changed Henry W. Coe State Park zone from tunnel to avoid.	Determine effect of some further constraints on alignments and corridor options.	NoGo zone created to the north of the study area to ensure all alignments were kept within the boundaries of the existing DTM.
PPASS_303 ♦ Start and Finish Points switch for better screen presentation. ♦ Added Special Zone "Henry W. Coe State Park as Tunnel zone and removed Avoid zones "Endangered" (for now). MaxCutFill set to 25m. ♦ Revised Geotype file to new unit costs. Max. 2.5% grades.	Determine effect of some further constraints on alignments and corridor options after discussion with Kip for presentation to PM and Geologist tomorrow morning.	NoGo zone created to the north of the study area to ensure all alignments were kept within the boundaries of the existing DTM.
PPASS_304 As per PPASS_303: ♦ Kept Max. 2.5% grade. ♦ Changed Henry W. Coe State Park zone from Tunnel to Avoid.	Determine effect of some further constraints on alignments and corridor options after discussion with Kip for presentation to PM and Geologist tomorrow morning.	NoGo zone created to the north of the study area to ensure all alignments were kept within the boundaries of the existing DTM.
PPASS_305 As per PPASS_301: ♦ Geotype file PPASS_06 retained with new unit rates. ♦ Special Zone file PPASS_06Q retained with Henry W. Coe Park Tunnel. ♦ Cost file revised to PPASS_02.csa with new Tunnel rate.	Optimization to determine the effect of new Tunnel rate.	
PPASS_306 As per PPASS_305: ♦ Changed Special Zone "Henry W. Coe State Park" from Tunnel to Avoid. ♦ Geotype file PPASS_06 retained with new unit rates. ♦ Cost file revised to PPASS_02.csa with new Tunnel rate.	Objective: Optimization to determine the effect of new Tunnel rate.	

PPASS_307 As per PPASS_304: ♦ Network file changed to PPASS_307 for 5% Max. grades. ♦ Special Zone file PPASS_07 retained with Henry W. Coe Park Avoid.	Optimization to find alignments at 5% Max. in the vicinity of SR130.	"North NoGo" Avoid zone added as a precautionary measure to guide the system away from considering alignments close to the edge of the DTM.
PPASS_308 As per PPASS_307: ♦ Network file PPASS_307 retained as 5% Max. grades. ♦ Special Zone file changed to PPASS_06Q Henry W. Coe Park Tunnel.	Optimization to find alignments at 5% Max. in the vicinity of SR130 or tunnel under park.	"North NoGo" Avoid zone added as a precautionary measure to guide the system away from considering alignments close to the edge of the DTM.

State Route (SR) 152 Alignment *(Refinement)*

Scenario Name and Description	Objective of Scenario	Outcome
PPASS_201 ♦ Endeavor to replicate Southern Pacheco Pass, mainly earthworks, alternative. ♦ Geotype, Geometric and Cost Inputs defined as per LA - Bakersfield project. ♦ Initial run optimization with maximum geometric constraints. ♦ No linear feature or special treatment zone constraints yet defined.	Determine corridor options to minimize costs of structures and earthworks for the longer, though less challenging terrain, southern route.	
PPASS_202 Southern Pacheco Pass, mainly earthworks, alternative. ♦ Revised Network file to correct Guide points to right Start/Finish points. Changed Profile Stiffness from 0.8 to 0.9 to improve vertical geometry as per LA - Bakersfield runs.	Test impact of various stiffness values.	
PPASS_203 Southern Pacheco Pass, mainly earthworks, alternative. ♦ Changed Profile Stiffness from 0.9 to 0.95 to improve vertical geometry as per LA - Bakersfield runs.	Test impact of various stiffness values.	
PPASS_204 ♦ Linear and Zone constraints as at 10/12/01 added. ♦ Geotype, Geometric and Cost Inputs defined as per LA - Bakersfield project. ♦ Special zone "Endangered13" changed to Ignored cut and fillPPASS_104.scn. ♦ Further optimization with maximum geometric constraints.	Determine effect of some initial constraints on alignments and corridor options.	

Scenario Name and Description	Objective of Scenario	Outcome
PPASS_205 ♦ Linear and Zone constraints as at 10/12/01 added. ♦ Geotype, Geometric and Cost Inputs defined as per LA - Bakersfield project. ♦ Further optimization with maximum geometric constraints.	Determine effect of some initial constraints on alignments and corridor options.	
PPASS_206 ♦ Start and Finish Points switch for better screen presentation. Moved (new) Start Point to better defines scope of investigation of this option. ♦ Added Special Zone "Henry W. Coe State Park as Tunnel zone and removed Avoid zones "Endangered" (for now). MaxCutFill set to 25m. ♦ Revised Geotype file to new units costs.	Determine effect of some further constraints on alignments and corridor options.	Seed alignment Start bearing incorrect.
PPASS_207 ♦ Start and Finish Points switch for better screen presentation. Moved (new) Start Point to better defines scope of investigation of this option. ♦ Added Special Zone "Henry W. Coe State Park as Tunnel zone and removed Avoid zones "Endangered" (for now). MaxCutFill set to 25m. ♦ Revised Geotype file to new units costs.	Determine effect of some further constraints on alignments and corridor options.	
PPASS_208 Same as PPASS_207: ♦ Used Linear Feature and Special Zones from PPASS_106. Added Special Zone "Floodplains and Farms". Revised all Road Linear Features to correct projection from Scott's data. ♦ 3.5% Max. grades.	Determine effect of floodplains and revised road constraints. Comparison between PPASS_107 and PPASS_108 3.5% and 2.5%.	
PPASS_209 Same as PPASS_208: ♦ Changed network file from 3.5% to 2.5% Max. grades.	Determine effect of floodplains and revised road constraints. Comparison between PPASS_207 and PPASS_208 3.5% and 2.5%.	
PPASS_210 As per Ppass_208: ♦ Network file changed to PPASS_210 for 5% Max grades.	Total Refinement of SR152 to find alignments at 5% Max. grades.	

Southern Mountain Crossing - Tehachapi Mountains

I-5/Grapevine Alternative A (Max. 2.5%) *(Refinement)*

Scenario Name and Description	Objective of Scenario	Outcome
HSR_I5_05 ♦ Updated Terrain file with CA_HSR60b.tmq. ♦ Revised Special Zone file as follows: Changed Sea22 Tunnel Zone to Ignored as Seed alignment is not in Tunnel in this vicinity. Changed Flood Special Zone to Ignored at CH10000 approx. as inappropriate in Sea22 Tunnel Zone. Changed Flood Special Zone to Ignored at CH13300 approx. as Seed alignment is in cut at this location, therefore in production of Seed alignment this zone was not considered to require >2m fill embankment. Changed Flood Special Zone to Ignored at CH56000-57000 approx. as Seed alignment is in cut at this location, as above. Perhaps re-introduce these constraints for Total optimization runs.		
HSR_I5_06 ♦ Total refinement of Seed I5 Alt A alignment by using the same constraints that were used to perform the total optimization for scenario HSR_03.	Produce a benchmark of I5 Alt A for Quantm comparison.	
HSR_I5_07 ♦ Added Special Zone "max cut fill" to limit cuts and fills to 35m. Changed Flood1 thru 4 from Unspecified to Structure. Changed SEA Prop 14 to Ignore. Duplicated SEA22 for Tunnel and Structure constraint.	To duplicate assumptions used to create seed alignment.	
HSR_I5_08 ♦ Changed special zone "max_cut_fill" to > -20 and <10. Changed various flood zone areas around chainage 20000 to structure. Changed SEA22 from Tunnel and Structure constraint back to Ignore due to earthwork limits changes.	To duplicate assumptions used to create seed alignment.	Quantm's seed alignment now appears to be very similar to P&D's.
HSR_I5_09 ♦ Same as HSR_I5_08_T: ♦ Changed profile stiffness from 0.8 to 0.95.		
HSR_I5_10 ♦ Changed Geozone to HSR_05 containing more accurate fault zones.		
HSR_I5_11 ♦ Same as HSR_I5BULT_06_T and HSR_I5_10_T. ♦ Removed no go zone to test options to east of Castac Lake at CH70000. Revised Special Zone flood areas to allow for Tunnel at the vicinity of Castac Lake. Removed special Zone flood areas incorrectly defined near CH 70000. ♦ Revised Geological type file with new unit costs.	To re-run I5_alt_A benchmark.	

I-5/Grapevine Alternative B Ultimate (Max. 3.5%) *(Refinement)*

Scenario Name and Description	Objective of Scenario	Outcome
HSR_I5BULT_01 New Run-I_5 Alternative B copied from hsr_i5_07_t with new network file.		
HSR_I5BULT_02 ♦ Refer to notes on HSR_07. ♦ Changed to the same Geozone and Special Zone file except fault zone was changed to Ignore.	Re-run HSR_I5BULT_01_T with new Geozone data.	Finish grade -2.53%, but design grade +-2.5% in network file caused violation near Finish point.
HSR_I5BULT_03 ♦ Refer to notes on HSR_I5BULT_03_T. ♦ Changed Max. grades from 2.5% to 3.5% (typo) ♦ Changed profile stiffness from .8 to 1.0.	Minimize undulation of vertical geometry.	As per HSR_08.SCN. Two scenarios were created for comparison: HSR_I5BULT_03_TQ1: V_stiffness = 0.95 HSR_I5BULT_03_TQ2: V_stiffness = 0.99
HSR_I5BUlt_04 Same as HSR_I5BULT_03_T: ♦ Changed profile stiffness from 0.8 to 0.95. ♦ Copy Special Zone from hsr_i5_10_t but altered Special Zone "max_cut_fill" to <28 to reflect seed alignment.	Minimize undulation of vertical geometry.	
HSR_I5BUlt_05 Same as HSR_I5BULT_04_T.	Test options to east of Castac Lake at CH70000 for possible excavation at Fault zone.	
HSR_I5BUlt_06 Same as HSR_I5bult_T: ♦ Removed no go zone to test options to east of Castac Lake at CH70000. Revised Special Zone flood areas to allow for tunnel at the vicinity of Castac Lake. Removed special Zone flood areas incorrectly defined near CH 70000. ♦ Revised Geological type file with new unit costs.	To re-run I5_ultb bench mark.	
HSR_I5BULT_07 Same as HSR_I5BULT_04_T: ♦ Changed Maximum grade to 4%.	See if alignment comes out of Tunnel near Castac Lake.	
HSR_I5BULT_08 As per HSR_I5BULT_07_T: ♦ Changed Max. grade to 3.5%.	Intensive Refinement to see if alignment can still daylight near Castac Lake. Note: HSR_I5BULT_07_T was the same as HSR_I5BULT_04_T except Max. 4% grades but should have been –4% but achieved the objective nevertheless.	

Scenario Name and Description	Objective of Scenario	Outcome
HSR_I5BULT_09 As per HSR_i5bult_08_T: ♦ Changed Special Zone "MaxCutFill" to >-35 & <35.	Intensive Refinement to minimize Tunnel length, particularly in the vicinity of the Fault zone, yet still daylight near Castac Lake.	
HSR_I5BULT_10 As per HSR_I5BULT_09_T: ♦ Changed Geotype file to HSR_13. Note HSR_02.gta has not been used since HSR_I5BULT_04_1I.opa (ie. includes HSR_I5BULT_07_T.scn, HSR_I5BULT_08_T.scn & HSR_I5BULT_09_T.scn. ♦ Also removed Special Zone Avoid for "Flood Castac".	As per HSR_I5BULT_09_T, Intensive Refinement to minimize Tunnel length, particularly in the vicinity of the Fault zone, yet still daylight near Castac Lake.	
HSR_I5BULT_11 As per HSR_I5BULT_10_T: ♦ Changed Geotype file to HSR_15. Note HSR_13.gta has had revised earthworks rates but Geotype "Fault Zone" earthworks had not been updated to revised unit rates. As example the Seed alignment used for this Intensive Refinement altered from $1.897B to $1,908B an additional 0.642% of original Seed cost. ♦ Also added back Special Zone Avoid for "Flood Castac" as this encourages day lighting near to the purposes of Refinement.	As per HSR_I5BULT_10_T, Intensive Refinement to determine effect of revised Fault Zone unit rates.	

I-5/Grapevine *(Optimization)*

Scenario Name and Description	Objective of Scenario	Outcome
HSR_02 ♦ Total Optimization with almost all constraints entered (only Fault geozone and some environmental zones, not yet defined, to be added).		Results created using new Terrain Model (TMQ). Cross violation occurs at the start section due to the railway (1st rail item in the Linear Feature dialog box) crossing requirement (>8 <-8m), while the Start Point is at the natural terrain level.
HSR_03 ♦ Changed SR-14 crossing clearance from >6 & <8 to >6 & <-8 (typo). Broke Rail Line string into 2 strings Rail 01 & Rail 02 and changed Rail 01 to Ignore in order to avoid bridge and violation at start point. Modified Special Zone, changed SEA2 from Avoid to Tunnel.	To find out if there are cheaper alternatives by tunneling through SEA2 zone.	

Scenario Name and Description	Objective of Scenario	Outcome
HSR_04 Same as Scenario HSR_03: ♦ Increased area of Seismic Zone ♦ Changed Park 100 from Avoid to Ignore.		
HSR_05 As per Scenario HSR_04: ♦ Added Fault triangle Avoid zone. ♦ Changed Max. grades from 2.5% to 3.5%. Moved Guide points to explore alignments to west of Fault triangle only.		
HSR_06 As per Scenario HSR_05: ♦ Changed maximum downhill grade to –5% to try minimize length of tunnel to 12 miles. ♦ Added Special Zone "max cut fill" to limit cuts and fills to 35m.		
HSR_07 As per Scenario HSR_06: ♦ Added Special Zone "Slide Zone 1 thru 7". Added large NoGo zones along fault lines. ♦ Extended Fault Geological zone roughly to the east and west.	Rerun of HSR_07 with more defined Fault Zones and Slide Zones.	
HSR_08 As per HSR_07: ♦ Changed profile stiffness from .8 to 1.0.	Try to minimize undulation of profile.	The current system is not able to handle stiffness = 1, but this will be easily fixed in the next update. High stiffness will produce high cost alignments with fewer curves. Two scenarios were created for comparison: CAHSRA-HSR_08Q1: V_stiffness = 0.95 CAHSRA-HSR_08Q2: V_stiffness = 0.99
HSR_09 As per HSR_08: ♦ Retained Profile Stiffness of 0.95. ♦ Reset Maximum downhill grade to -3.5%. ♦ Revise shape of Fault zone to encourage alignments to the west.	Avoid Fault zone whilst trying to minimize undulation of profile.	
HSR_10 As per HSR_09: ♦ Retained Profile Stiffness of 0.95. Further revised shape of Fault zone and guide posts to encourage alignments to the west.	Avoid Fault zone while trying to minimize undulation of profile.	Several special flood zones just to the north west of the triangular fault void zone were modified to Ignore. This was due to the fact that these zones required a 2m relative clearance, which conflicted with the alignment in tunnel in that section.

Scenario Name and Description	Objective of Scenario	Outcome
HSR_11 As per HSR_10: ♦ Increased Plan Stiffness from 0.8 to 0.9.	Plan Stiffness Sensitivity testing.	Several special flood zones just to the north west of the triangular fault void zone were modified to Ignore. This was due to the fact that these zones required a 2m relative clearance, which conflicted with the alignment in tunnel in that section.
HSR_12 As per HSR_10: ♦ Increased Plan Stiffness from 0.8 to 0.7.	Plan Stiffness Sensitivity testing.	Several special flood zones just to the north west of the triangular fault void zone were modified to Ignore. This was due to the fact that these zones required a 2m relative clearance, which conflicted with the alignment in tunnel in that section.
HSR_13 As per HSR_10Q: ♦ Revised Special Zone flood areas to allow for tunnel in the vicinity of Castac Lake. Removed flood areas incorrectly defined near CH 70000. ♦ Revised Geological type file with new unit costs.	To re-run optimization with new unit costs.	
HSR_14 Same as HSR_14: ♦ Changed Max. 2.5% grades.	To do an Optimization Comparison between 3.5% and 2.5% grades.	

SR-58/Mojave (Max. 2.8%) *(Refinement)*

Southern Section

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SOLSR58_09 Total refinement of seed SOLSR58 alignment by using the same constraints that were used to perform the total optimization for scenario HSR_03.	Produce a benchmark of SOLSR58 for Quantm comparison.	
HSR_SOLSR58_10 As per SOLSR58_09_T: ♦ Changed linear constraints for Rail through Palmdale from structure to ignore.	Produce a benchmark of SOLSR58 for Quantm comparison.	Changed to Intensive Refinement due to horizontal violations near the start. Crossing violations still occur in the Avoid zones at the beginning similar to HSR_SOLSR58_09. A slight increase in bearing at the start point may solve this problem.

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SOLSR58_11 ♦ Added Special Zone "max cut fill" to limit cuts and fills to 35m. Added "Km145000_by_the_loop" to reduce max cut and fill to 14m. Added "Lancaster structure" and "Palmdale structure". Flood5, 6 & 7 Ignore as Seed alignment is in cut. Insert "Bridge1" and "Tunnel1" to force Structure as per Seed. ♦ Split Linear Feature "Rail_at_104000" into Ignored and Structure.	To duplicate assumptions used to create seed alignment.	
HSR_SOLSR58_12 Same as HSR_SOLSR58_11_T: ♦ Changed Special Zone "max_cut_fill" to >-15 and <18. Changed some flood areas from Unspecified to Ignored due to seed alignment being in cut. ♦ Changed profile stiffness from 0.8 to 0.95.	To duplicate assumptions used to create seed alignment.	
HSR_SOLSR58_13 Same as HSR_SOLSR58_12_T: ♦ Updated new Geotype zone with new unit costs.		Two special avoid zones (urban98 & Urban99) in the start section were modified and an Intensive Refinement processed rather than Refinement.

SR-58/Mojave Ultimate (Max. 3.5%) *(Refinement)*

Southern Section

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SOLSR58ULT_01 Based on HSR_SOLSR58_12_T. Profile Stiffness of 0.95 assumed based on other scenarios to date.	To duplicate assumptions used to create seed alignment.	
HSR_SOLSR58ULT_02 Based on HSR_SOLSR58_12_T: ♦ Profile Stiffness of 0.95 assumed based on other scenarios to date.	To duplicate assumptions used to create seed alignment.	As per HSR_SOLSR58_13, updated HSR_SOLSR58_12.SZA was used was modified for an intensive refinement. And also please ensure that the
HSR_SOLSR58ULT_03 Based on HSR_SOLSR58ULT_02_T: ♦ Special Zones "Urban1 & Urban2" adjusted to allow optimization. "Tunnel1" altered to Relative < 0. Note this was previously set to Absolute < 0 (input error). ♦ Network file revised to finish at Palmdale. Guide Points altered.	To duplicate DMJM Seed alignment assumptions and run full optimization from Sylmar to Palmdale.	

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SOLSR58ULT_04 Same as HSR_SOLSR58ULT_03_T: ♦ Changed End Grade from 2.8% to 2.5%. Changed Max. 2.5% grades.	To run an optimization and total and vertical refinement.	
HSR_SOLSR58ULT_05 Based on HSR_SOLSR58ULT_03_T: ♦ Special Zones "Tunnel1" altered to Ignored.	Optimization, Total & Vertical Refinements at 3.5% without Floodplain Tunnel constraint.	
HSR_SOLSR58ULT_06 Based on HSR_SOLSR58ULT_05_T: ♦ Special Zones "Tunnel1" altered to Ignored. ♦ Network file saved as SOLSR58ULT_06.nwa with Max. 2.8% grades.	Optimization, Total & Vertical Refinements at 2.8% without Floodplain Tunnel constraint.	
HSR_SOLSR58ULT_07 Based on HSR_SOLSR58ULT_06_T: ♦ New Special Zones file created with "Tunnel1" still Ignored. Changed "Bridge1" to Ignored, "Max_Cut_Fill" to >-40 & <40 & "KM145000_by_the_loop" to Ignored. ♦ Network file replaced with SolSR58ult_03.nwa (Max. 3.5% grades).	Total Intensive Refinements as comparison with PB's Corridor Evaluation Alignment.	

SR-14 Alternative (Max. 3.5%) *(Refinement)*

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SR14SR58_01 New Run-HSR_I5BULT_01_T copied from HSR_I5_07_T with new network file.		Crossing violations occur in the V shape fault zone. To avoid the fault zone completely, then define the zone in a big triangle rather than a V shape.
HSR_SR14SR58_02 Same as HSR_SR14SR58_01TQ: ♦ Changed Geotype file to represent new unit costs. ♦ Changed network file because previous network was wrong.	To create a similar alignment to be compared with seed alignment.	Intensive refinement performed to produce better results.
HSR_SR14SR58_03 Same as HSR_SR14SR58_02_T: ♦ Forgot to change profile stiffness to 0.95.	To create a similar alignment to be compared with seed alignment.	Intensive refinement performed to produce better results.

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SR14SR58_04 Same as HSR_SR14SR58_03_T: Changed Special Zone for Flood Zones from Unspecified to Ignore at KM 125000 to remove crossing violation. Changed max_cut_fill to >-15 and <18.	To create a similar alignment to be compared with seed alignment.	
HSR_SR14SR58_05 Same as HSR_SR14SR58_04_T: Changed network file. Wrong location of Guide Points and wrong max and min grade. Changed Max. grades from 2.2% to 2.62%. (Refer to seed file).	To create a similar alignment to be compared with seed alignment.	
HSR_SR14SR58_06 Same as HSR_SR14SR58_05_TI: ♦ Changed network file. Change grades from 2.62% to 2.5%.	To create a comparison between 2.62%, 2.5% and 3.5% grade using seed alignment.	
HSR_SR14SR58_07 Same as HSR_SR14SR58_05_TI: ♦ Changed network file. Change grades from 2.62% to 3.5%.	To create a comparison between 2.62%, 2.5% and 3.5% grade using seed alignment.	
HSR_SR14SR58_101 As per HSR_SR14SR58_07_TI: ♦ Changed network file to southern section only, SOLSR58ULT_04.	To create a comparison between 2.62%, 2.5% and 3.5% grade using seed alignment to test against Soledad SR58 alignments.	
HSR_SR14SR58_102 As per HSR_SR14SR58_07_TI: Changed network file to southern section only, SOLSR58ULT_04.	To create a comparison between 2.62%, 2.5% and 3.5% grade using seed alignment to test against Soledad SR58 alignments.	
HSR_SR14SR58_103 As per HSR_SR14SR58_101_T: ♦ Southern section only. ♦ Network file changed to Max. 3.5% grades.	To create a comparison between 2.62%, 2.5% and 3.5% grade using seed alignment to test against Soledad SR58 alignments.	
HSR_SR14SR58_104 As per HSR_SR14SR58_103_T and HSR_SOLSR58ULT_07_T: ♦ Special Zone file changed to HSR_SOLSR58_14 to make consistent with HSR_SOLSR58ULT_07_T. ♦ Network file changed to SOLSR58ULT_03. Still Max. 3.5% grades but -2.8% Finish Grade.	To create a comparison between 2.62%, 2.5% and 3.5% grade using seed alignment to test against Soledad SR58 alignments.	

Northern Section (Max. 3.5%) *(Refinement)*

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SOLSR58ULT_201 Based on HSR_SOLSR58ult_04_T: ♦ Max. 3.5% grades.	To create a total comparison using 3.5% and 2.5% for the northern segment of HSR_Solsr58ult seed.	Guide Point location does not correlate with the newly defined Start & Finish Point locations. Resubmit scenario.
HSR_SOLSR58ULT_202 Based on HSR_SOLSR58ult_04_T: ♦ Max. 2.5% grades.	To create a total comparison using 3.5% and 2.5% for the northern segment of HSR_Solsr58ult seed.	Guide Point location does not correlate with the newly defined Start & Finish Point locations. Resubmit scenario.
HSR_SOLSR58ULT_203 Based on HSR_SOLSR58ult_201_T: ♦ Error on location of Guide Points. Max. 3.5% grades.	To create a total comparison using 3.5% and 2.5% for the northern segment of HSR_Solsr58ult seed.	
HSR_SOLSR58ULT_204 Based on HSR_SOLSR58ult_202_T: ♦ Error on location of Guide Points. Max. 2.5% grades.	To create a total comparison using 3.5% and 2.5% for the northern segment of HSR_Solsr58ult seed.	
HSR_SOLSR58ULT_205 Based on HSR_SOLSR58ult_204_T: ♦ Network file saved as SOLSR58ULT_205.nwa with Max. 2.8% grades.	Optimization, Total & Vertical Refinements at 2.8%.	
HSR_SOLSR58ULT_206 Based on HSR_SOLSR58ULT_07: ♦ New Special Zones file created with "Tunnel1" still Ignored. Changed "Bridge1" to Ignored, "Max_Cut_Fill" to >-40 & <40 & "KM145000_by_the_loop" to Ignored. ♦ Network file replaced with SOLSR58ULT_203.nwa (Max. 3.5% grades).	Total Intensive Refinements as comparison with PB's Corridor Evaluation Alignment.	

SR-138/Palmdale

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SR138_01 Same as HSR_SR14SR58_11_T: ♦ Profile Stiffness of 0.95 assumed based on other scenarios to date.	To duplicate assumptions used to create seed alignment.	
HSR_SR138_02 ♦ Changed network file. Changed Guide Points and Start and Finish Points. Max.2.62% grades.	To duplicate assumptions used to create seed alignment.	Crossing violation at CH 36200 and 36800 reflects the same violation encountered with the HSR_10 - _12 scenarios. Modifying the flood zones to Ignore whilst the alignment is in Tunnel should produce better results.

Scenario Name and Description	Objective of Scenario	Outcome
HSR_SR138_03 ♦ Changed network file. Changed Max. grades from 2.62% to 2.5%.	To do a comparison between the 2.62%, 2.5% and 3.5% grade.	
HSR_SR138_04 ♦ Changed network file. Changed Max. grades from 2.62% to 2.5%.	To do a comparison between the 2.62%, 2.5% and 3.5% grade.	
HSR_SR138_05 ♦ Changed network file. Changed Guide Points and Start and Finish points. Max. 2.62% grades. ♦ Changed special flood zones to allow for Tunnel.	To duplicate assumptions used to create seed alignment.	
HSR_SR138_06 ♦ Changed network file. Changed Max. grades from 2.62% to 2.5%. ♦ Total Optimization at max. 2.5% grades.	To do a comparison between the 2.62%, 2.5% and 3.5% grade.	
HSR_SR138_07 ♦ Changed network file. Changed Max. grades from 2.62% to 3.5%. ♦ Total Optimization at 3.5% grades.	To do a comparison between the 2.62%, 2.5% and 3.5% grade.	